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By

Hyung Sok Choe

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The Dissertation Committee for Hyung Sok Choe Certifies that this is the approved version of the following dissertation:

Engineering Identity and Research Identity: Relationship between Engineering Graduate Students' Identities and their Career Trajectory

Committee:

Maura Borrego, Supervisor

Catherine Riegle-Crumb

Carolyn Seepersad

Mia Markey

Engineering Identity and Research Identity: Relationship between Engineering Graduate Students' Identities and their Career Trajectory

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Hyung Sok Choe

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Engineering Identity and Research Identity: Relationship between Engineering Graduate Students' Identities and their Career Trajectory

by

Hyung Sok Choe, PhD

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The purpose of this dissertation is to contribute to the understanding of engineering graduate students' engineering identity and research identity and of how these identities influence their career intentions. This quantitative research study involves the development of a survey instrument to examine the engineering identity and research identity of students. A total of 320 master's and doctoral students from one large public research university within three disciplines completed the survey.

This dissertation is composed of three studies. The focus of the first study is to understand whether engineering identity measurement frameworks studied for undergraduate students also apply to graduate students, how the frameworks correlate with intention to complete the degree, and what predicts the engineering identity of engineering master's and doctoral students. Factor analyses identified four factors that relate to graduate engineering identity: engineering interest, engineering recognition, engineering competence, and interpersonal skills competence. In the multiple regression models, student characteristics and the four factors predict 60% of the variance in engineering identity. All four factors were significant and positive predictors of graduate students' engineering identities.

The second study focus is to investigate differences between the engineering identity development of US and non-US graduate students by utilizing t-tests interaction factors in a linear regression model. A main finding is that most of the engineering graduate identity constructs investigated were significantly different between US and non-US students, including research interest/recognition, engineering recognition, math/science competence, engineering competence, and interpersonal skills competence. This second study also presents three significant interactions between engineering graduate identity constructs and citizenship status.

In the third study, the purpose is to understand engineering graduate students' intentions in industry, academia, and government careers as it relates to their graduate engineering identities by utilizing multiple linear regression, a cluster analysis, and multinomial logistic regression. Overall, higher research interest/recognition and math/science competence were related to a greater likelihood of pursuing academia or government, while higher engineering interest and recognition were related to a greater likelihood of pursuing industry. Cluster analysis yielded three career path profiles: prefer industry, prefer academia, and open to all career options. Few students were considering academic careers exclusively.

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Chapter 1: Introduction

In the United States, engineering graduate degrees are increasingly valued by various industries for skills like conducting research and integrating the newest engineering technologies (Brown & Linden, 2008). Fiegener (2011) reported that 38% of US engineering doctoral degree recipients worked in industrial positions and 45% in academic positions (including faculty and postdoctoral research positions). Although research on academic career intentions for doctoral students has been well studied (Austin, 2002; Laursen, Thiry, & Liston, 2012; Nauta, Epperson, & Kahn, 1998), studies on industrial career intentions are very thin.

Several researchers have proposed disciplinary identity development as a new lens for understanding graduate student career intentions (Castelló et al., 2015; Lamar & Helm, 2017; Robnett, 2012). Among graduate students, higher disciplinary engineering identity has been linked to career intentions in the engineering field (Burt, 2014; Chu, 2006).

The goal of this dissertation is to contribute to the understanding of how engineering graduate students' engineering identity and research identity development can be related to career paths. Park (2017) conducted a longitudinal qualitative study on professional identity development of counseling doctoral students, and he found that counseling doctoral students develop two different professional identities, counselor identity and research identity, during their graduate programs. He found that counseling doctoral students had to develop two distinguished skill sets during their time in graduate school so that they develop two different professional identities. In the case of engineering graduate students, I assume that they also need to develop two different natures of disciplinary skills, engineering and research, so that they may develop different engineering and research identities.

Engineering identity has mainly been investigated with undergraduate engineering students (Godwin, Potvin, Hazari, & Lock, 2016; A.D. Patrick, N.H. Choe, et al., 2017; Prybutok, Patrick, Borrego, Seepersad, & Kirisits, 2016), so the literature on graduate students' engineering identity development is relatively sparse. Also, the phenomenon has been investigated mostly using qualitative approaches (Burt, 2014; Chu, 2006). Another aspect of graduate students' engineering identities compared to undergraduates is their research-related identity development, since the purpose and nature of many graduate degrees is to develop students as independent researchers (Council of Graduate Schools, 2005). Engineering graduate students are influenced by a research-related sociocultural environment that is significantly related to their identity development (Park, Choe, Schallert, & Forbis, 2017). Research identity development has been studied with non-engineering doctoral students, but very few researchers have investigated engineering graduate students' research identities.

Further, this dissertation study will also highlight identity development differences between international and domestic students because of the high representation of international students in US engineering graduate programs. Yoder (2015) reported that approximately 50% of engineering graduate students in US research universities are international students. International students bring educational and cultural backgrounds from their home countries that are different from those of domestic students; thus, it will be worthwhile to compare international and domestic students' engineer and research identity development.

Study Rationale

Career support for industry employment following US engineering graduate study has not been well investigated. Multiple studies suggest stronger STEM identity as one way to aid students' persistence in STEM graduate programs and fields (Robnett, 2012). Therefore, engineering graduate students' successful development of engineering and research identities may provide possible approaches for increasing their completion rate in engineering graduate programs and choosing their career paths in engineering fields. Drawing from Godwin (2016) and Prybutok et al.'s (2016) undergraduate engineering identity model, which contains three constructs (competence/performance, interest, and recognition), this study will contribute to understanding engineering graduate students' identity constructs, both in engineering and in research. These engineering graduate identity constructs, which include both engineering and research identities' components, involve students' various experiences associated with class, lab, and research work among others. This study posits that graduate students' engineering and research identities are likely to intersect while also developing separately.

I developed a survey instrument to measure both the engineering identities and the research identities of graduate students as well as key factors affecting engineering graduate students' identity formation. The survey instrument contributes to a greater understanding of how intentions to graduate are affected by engineering identity and the research identity. Further, I explored engineering identity and research identity differences between international and domestic students in engineering programs that have a high representation of international students.

Brief Description of Analytical Chapters

In this dissertation, I present three analytical chapters, in manuscript format, that address the engineering identities and research identities of engineering graduate students. Through these studies, I make the argument that graduate students' engineering and research identities are not only carried from their prior experience in undergraduate programs but also developed within the sociocultural environment of engineering graduate programs. Collectively, my three analytical chapters address the engineering and research identities of engineering graduate students.

The second chapter (first manuscript) focuses on the development of the survey instrument that measures engineering identity for the engineering graduate student population. I utilize both exploratory and confirmatory factor analyses to label constructs of engineering identity for graduate students as well as explore how these constructs of engineering identity predict students' engineering identities. There are three research questions for this first analytical chapter.

1. Do engineering identity measurement frameworks studied for undergraduate students also apply, with adaptation, to graduate students?
2. Do these adapted measures correlate with engineering graduate students' intention to complete their degree?
3. What student characteristics and components of engineering identity predict the engineering identity of engineering master's and doctoral students?

The third chapter (second manuscript) focuses on the differences in engineering identity and research identity between US and non-US students. In addition, I investigate how citizenship interacts between engineering identity and research identity utilizing interaction effects in linear multiple regression models. The four research questions guiding this analysis are:

1. Do US and non-US engineering graduate students differ in engineering identity and engineering graduate identity constructs?
2. Is engineering identity different for engineering graduate students by gender, nationality (US vs. non-US), undergraduate discipline (engineering vs. science), work experience, or career trajectory?

3. What constructs of engineering graduate students' engineering graduate identity predict their engineering identities?
4. Do associations between engineering identity and engineering graduate identity constructs differ significantly between US and non-US students in engineering graduate programs?

The fourth chapter (third manuscript) explores how engineering graduate identity predicts students' career intentions using multinomial logistic regression models. I utilize a cluster analysis method to understand how students can be categorized by career intention into three different sectors (industry, academia, government) and how these categorizations can be predicted by students' engineering identities and research identities. Three research questions from this third analytical chapter are:

1. What student characteristics and components of engineering graduate identity predict engineering graduate students' career paths toward industry, academia and government?
2. What are the characteristic profiles of how engineering graduate students are considering the relative likelihood of careers in industry, academia, and government?
3. What student characteristics and components of engineering graduate identity predict these characteristic profiles of engineering graduate students' career paths?

In the conclusion section of this dissertation, I summarize the results and discuss how these three analytical chapters contribute to engineering education to produce a better understanding of engineering graduate students' engineering identity and research identity development.

Chapter 2: Manuscript one

Prediction of Engineering Identity in Engineering Graduate Students

Abstract (This chapter is published at *IEEE Transactions on Education)*

Identity is a new lens to understand students' persistence in engineering, as students who identify as an engineer are more likely to persist. A few studies investigate engineering identity development in undergraduate students, but more work is needed focusing on graduate students. The aim of this research is to model engineering identity in graduate students through adaptation of measures previously validated for undergraduates. Interviews informed development and adaptation of a multi-scale survey instrument. Exploratory Factor Analyses (EFA) and Confirmatory Factor Analysis (CFA) identified four factors that relate to graduate engineering identity: engineering interest, engineering recognition, engineering competence, and interpersonal skill competence. The engineering recognition factor in particular needed adaptation to emphasize peers and faculty members over family, although family remained important. Three sequential multiple linear regression models were used to predict engineering graduate students' engineering identity. The final model, which includes student characteristics and the four factors resulting from CFA, predicts 60% of the variance in engineering identity. This is substantially more than similar undergraduate engineering identity models. All four factors were significant and positive predictors of graduate students' engineering identity. In addition, having earned a bachelor's degree in engineering, an additional type of recognition, was a positive and significant predictor of engineering identity.

2.1 Introduction

The Council of Graduate Schools (2008) reports that the six-year completion rate for US engineering graduate degrees has held steady at just 50% for the past several decades, despite consistent efforts to increase enrollment and persistence of engineering graduate students. Several researchers have proposed disciplinary identity development as a lens for understanding graduate student persistence (Castelló et al., 2015; Hallonsten & Heinze, 2012; Lamar & Helm, 2017). In STEM fields, there is some evidence stronger disciplinary identity is correlated with persistence in graduate programs. For example, Robnett (2012) postulated that graduate student attrition is related to STEM disciplinary identity. Chemers, Zurbriggen, Syed, Goza, and Bearman (2011) reported that STEM identity of was a positive predictor of graduate student persistence and career choice in STEM fields. Additionally, there are several similar studies on undergraduate students that relate STEM identities to persistence in STEM fields. The survey results of Cundiff, Vescio, Loken, and Lo (2013) show that science majors who have high science identification are more likely to intend to persist in science fields. Similarly, Merolla, Serpe, Stryker, and Schultz (2012) reported that the science identity salience of undergraduate students was crucial to commitment to a science field and an intention to pursue a science field. Cribbs, Cass, Hazari, Sadler, and Sonnert (2016) found that mathematics identity was a significant factor that predicts students' engineering career choice.

There is also relevant literature on undergraduate engineering students' engineering identity development. Meyers, Ohland, Pawley, Silliman, and Smith (2012) reported that undergraduate students who identified as engineers were more likely to state they would continue their education and career in engineering-related fields. Godwin, Potvin, Hazari, and Lock (2013) found that first-year undergraduate students who self-identify as engineers have higher intention to complete their degree and are more likely to pursue an undergraduate engineering major or career. For undergraduates across all four years, engineering interest, a component of identity, was a positive and significant predictor for one year persistence in engineering programs (Prybutok et al., 2016).

However, engineering identity has primarily been investigated for undergraduate students (Godwin et al., 2013; A.D. Patrick, Borrego, & Prybutok, 2018; Prybutok et al., 2016), leaving a sparse literature on graduate student engineering identity, excepting a few qualitative studies (Burt, 2014; Chu, 2006). This study focuses on engineering identity of engineering graduate students, specifically measuring and predicting engineering identity and understanding relationships between engineering identity and persistence in graduate students. The research questions are

1. Do engineering identity measurement frameworks studied for undergraduate students also apply, with adaptation, to graduate students?
2. Do these adapted measures correlate with engineering graduate students' intention to complete their degree?
3. What student characteristics and components of engineering identity predict the engineering identity of engineering master's and doctoral students?

This work will enable future studies of how engineering identity develops in graduate students, the implications of engineering identity for persistence at the graduate level, and how engineering identity influences decisions to pursue graduate study. Additionally, it will inform engineering graduate programs about developing strong engineering identities and supporting graduate retention.

2.2 Literature Review

According to Gee's (2000) multiple identity theory, an individual holds or develops their multiple types of identities which connect to their performances in society. This is the basis of several prior studies of engineering, science and math identity. Some of the multiple identities that may apply to engineering graduate students include student, teacher, researcher, and engineer, in addition to identities associated with gender, race and other personal characteristics. This paper focuses on engineering identity by expanding work with undergraduates to the graduate level. According to several studies on undergraduate engineering identity (Capobianco, French, & Diefes-Dux, 2012; Meyers et al., 2012), engineering students develop their engineering identity during their undergraduate program. The more extensive literature on undergraduate student engineering identity development can provide a foundation to understand engineering identity development in engineering graduate students.

Studies of undergraduate engineering identity have tended to adapt science and math identity studies to focus on the disciplinary aspects of engineering identity. In science, identity as composed of recognition, performance/competence, and interest factors, is used as a predictor of career choice and intent to persist persistence in STEM fields (Carlone & Johnson, 2007; Hazari, Sonnert, Sadler, & Shanahan, 2010). Engineering education researchers have adapted these three academic (as opposed to professional) factors to develop engineering identity measures for undergraduates (Godwin, 2016b; A.D. Patrick et al., 2018; Prybutok et al., 2016). Performance/competence describes a student's belief in their ability to perform academically or when conducting engineering-related tasks, and their ability to understand engineering material. Interest describes how motivated a student is towards the content and career they are pursuing, often encompassing the motives a student has for pursuing graduate study. Interest encompasses not only affinity towards engineering tasks but also the ongoing reasons students identify for persisting in engineering. Recognition describes how others such as parents, relatives, friends, colleagues, and faculty see the student in the context of engineering. How that message is transferred to the student often affects their self-recognition, i.e., their identification as engineers. All three of these factors are positive and significant predictors in regression models of engineering identity. A.D. Patrick et al. (2018), explained 27% of the variance in engineering identity of undergraduates using this framework. In a related data set, Choe, Martins, Borrego, and Kendall (in press) explained 8.4% of the variance in engineering identity of undergraduates using these same factors. In both cases, engineering interest was the strongest positive predictor, followed by engineering recognition by others and engineering performance/competence.

Engineering identity can be defined as the knowledge, emotions, skills, and experiences that are organized around a particular professional role (Eliot & Turns, 2011). Thus, engineering identity is unique compared to science and math identity because engineering identity refers to both discipline and profession whereas science and math identity is primarily disciplinary. Through the addition of factors to capture affinity toward professional aspects of engineering practice, Choe et al. (in press) were able to explain 8.4% of the variance in engineering identity of undergraduates. Professional skills are also an important consideration for engineering graduate students (Zhu, Cox, Branch, Ahn, & London, 2013).

Although master's and doctoral students' engineering identity is likely different from that of undergraduates, the majority of engineering graduate students hold bachelor's degrees in engineering, and these students have developed their engineering identity during undergraduate engineering programs. Thus, the undergraduate engineering identity scale is a suitable basis for developing engineering graduate students' engineering identity scale.

2.3 Method

2.3.1 Overview

This paper describes six phases of instrument development and validation. For the pilot study, survey responses were collected from 115 students in Spring 2017 and conducted the first exploratory factor analysis (EFA) for the first item reduction. In Spring 2018, 320 graduate students completed the revised survey. A second round of EFA was conducted on a randomly split sample of the data to examine the factor structure of engineering identity. A confirmatory factor analysis (CFA) was conducted on the holdout sub-sample from Spring 2018 which was not included in the EFA. Finally, a sequential multiple linear regression was conducted to predict engineering identity with the four independent variables which resulted from the CFA.

2.3.2. Demographic Information Items

In all versions of the survey, participants were asked their gender, nationality, engineering disciplines, types of the program, higher education degrees (e.g., bachelor's or master's degree) in engineering fields, work experience in engineering prior to graduate programs, and internship experience during their graduate programs in the survey.

2.3.3. Dependent Variable Items

In all versions of the survey, participants answered a 5-point Likert scale of engineering identity items. A total of five items were borrowed from Plett, Hawkinson, VanAntwerp, Wilson, and Bruxvoort (2011) to measure engineering identity as a dependent variable. In the previous work of Choe et al. (in press), EFA results in retaining four of the items with a 0.83 Cronbach's alpha measure of internal consistency. Example items are "I consider myself an engineer" and "being an engineer is an important reflection of who I am."

2.3.3. Instrument Development for Independent Variables

2.3.3.1. Identifying and Describing Behaviors that Underlie the Factor

Since previous instruments had been validated for undergraduates, several key informants were interviewed to provide context about graduate students' experiences as they related to their engineering identities. The key informants from mechanical engineering were one PhD engineering faculty member, one PhD postdoctoral fellow, one PhD engineer in industry, and four PhD and two master's students. All interviewees were either employed by or alumni of the same large public research university where survey data were collected. Some of the interview questions were “do you consider yourself an engineer?”, “do you consider yourself a researcher?” and “describe a moment when you felt you were doing well in engineering? What contributed to this success?”

2.3.3.2. Development of Initial Instrument

In this phase, the authors borrowed, adapted and generated items to address the study's framework of engineering interest, engineering competence, and engineering recognition from others, as well as interpersonal skill competence to begin to address professional aspects of engineering practice. All versions of the survey used a 5-point Likert scale for responses. Five expert reviewers provided feedback on the initial 65 items. Three were engineering faculty members, and the other two were working as engineers in industry. Individual reviewers provided feedback on each item to evaluate whether these items were appropriate descriptors of engineering identity as defined, and to provide alternative suggestions where needed. Finally, they provided feedback on the overall instrument including additional items to include.

2.3.3.3. Initial Item Reduction

The pilot version of the survey was completed in Spring 2017 by 115 mechanical engineering graduate students from one large public university. The survey was distributed via email by a mechanical engineering department administrator.

An exploratory factor analysis was conducted to investigate the factor structure underlying the new items and eliminate either irrelevant or cross loaded items. An initial set of 48 items was reduced to 27 items after the item elimination process (Field, 2009). Preliminary analysis of survey development results was presented in a conference paper (Choe, Borrego, Martins, Patrick, & Seepersad, 2017). These pilot EFA results indicated that the engineering competence, engineering interest, and interpersonal skills competence items factored as expected, with four item each and Cronbach's alphas ranging from .67 to .88. The engineering recognition factor did not emerge as expected during this round of EFA.

2.3.3.4. Adding Items and Expanding Engineering Disciplines

Prior to full data collection in Spring 2018, 7 items were added to capture recognition and boost internal consistency values for some factors. Although previous interviews indicated that engineering recognition from others was an important part of their engineering identity, the initial item reduction process did not yield an engineering recognition factor. The authors suspected this was because undergraduate measures of engineering recognition rely heavily on family and friends. Thus, several items were added that reflect recognition by individuals from academia and industry. Example items are “other students in my program see me as an engineer,” “my advisor expects me to continue my career as an engineer,” and “industry researchers value my work.”

Additional interviews were conducted with electrical/computer and civil/environmental engineering graduate students to verify a similar interpretation of survey items. In addition, interviewees were asked whether these items captured their engineering graduate experiences. Six graduate engineering students participated in these interviews, one master's and two doctoral students for each discipline. The interviews confirmed that the first set of survey items was properly worded for their disciplines and communicated the meaning of the survey items as intended.

2.3.3.5. Exploratory Factor Analysis for Engineering Identity

An exploratory factor analysis was again used to check if newly added items were reflecting initially hypothesized factors and to conduct another around of item reductions. The final set of items was administered via an online survey to electrical/computer, civil/environmental, and mechanical engineering graduate students along with dependent variable and demographic items. The surveys were distributed via an email invitation from the electrical/computer, civil/environmental, and mechanical engineering graduate student coordinators to all current graduate students in those departments at a large public research university. The graduate students were able to access surveys via the online survey tool, Qualtrics. The graduate coordinator sent one email invitation and two weekly reminders. Participants who completed the survey were entered into a drawing for one of two $50 gift cards.

A total of 320 graduate students completed the survey resulting in a response rate of 26%. Among respondents, 183 were doctoral students, 66 were thesis master's students, and 71 were non-thesis master's students. Seventy-six participants self-identified as women, 244 as men. Of 320 students, 131 domestic, 156 international, and 33 unidentified students completed the survey. In terms of engineering discipline, 135 were electrical/computer engineering students, 105 were civil/environmental engineering students, and 80 were mechanical engineering students.

A sub-sample (n = 120) was used to conduct an EFA on the 34 items to assess the independent variables related to engineering identity factors. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was recommended when the ratio between variables and sample size are less than 1:5 (Hair, Anderson, Tatham, & Black, 1995), (Tabachnick & Fidell, 2007). The KMO measure of sampling adequacy was 0.86, exceeding the recommended minimum of 0.60. The other EFA assumption test was also conducted. Bartlett's test of sphericity value was ($X^2(210) = 1630.10$, $p<0.0001$), less than the 0.05 threshold to verify homogeneity of item variances (Snedecor & Cochran, 1989).

There two tests ensured that the survey scales were appropriate to conduct EFA. Principal Axis Factoring (PAF) extracting and Oblique (non-orthogonal) rotation were used in the EFA.

2.3.3.6. Confirmatory Factor Analysis

A confirmatory factor analysis was conducted on the reduced set of items resulting from previous procedure using a holdout sub-sample from the final set (n=200), i.e, the responses not used for EFA. CFA with at least 200 sample sizes is a threshold for “low risk of drawing wrong conclusion”(Anderson & Gerbing, 1984). Thus, this study split the final data unevenly for EFA and CFA. The goodness of fit of the factor structure was examined using several indices including Comparative Fit Index (CFI), Tuck Lewis Index (TLI), Chi-square, and the root mean square error of approximation (RMSEA). Modification indices were also examined to identify potential cross-loadings. The final version was examined for internal consistency using Cronbach’s alpha.

2.3.3.7. Correlations and Regression Analysis

Pearson correlations were calculated to investigate relationships between intention to complete the graduate degree, the dependent variable of engineering identity, and the independent variables assessing factors expected to affect graduate students’ engineering identity.

Three multiple linear regression models were conducted to identify which student characteristics and identity factors were significant in predicting engineering identity of engineering graduate students.

Prior to regression analysis, several assumptions of sequential multiple linear regressions were tested. Linearity, homoscedasticity, and normality were confirmed via scatter and Q-Q plots. Additionally, Variance Inflation Factors (VIF) coefficients were less than 2, an indication of no multicollinearity issues in the regression models (Slinker & Glantz, 1985).

The regression models to predict engineering identity have three steps. In step one, the seven student characteristics were entered: gender, nationality, engineering discipline, current degree program, obtained engineering bachelor’s degree, engineering work experience prior to graduate program, and internship experience during graduate program. In step 2, three factors used in several other studies of engineering identity were added: engineering interest, engineering competence, and engineering recognition. Then interpersonal skills competence was added in Model 3.

For control variables, all control variables were dummy-coded; the reference group does not appear in the regression table. Male was a reference group for gender. US citizens were the reference group, comparison with international students for nationality. For engineering discipline, electrical/computer engineering was the reference group for civil/environmental and mechanical engineering. For current degree program, Ph.D. degree was the reference group for comparison with Master's degree without thesis and Master's degree with thesis. For obtained engineering bachelor's degree, the students without engineering bachelor's degree was the reference group for comparison with the students with a bachelor's degree in engineering. For work experience in engineering prior to graduate program, the students with no work experience prior to their current graduate program was the reference group compared to students with work experience. For internship experience during graduate program, the students with no internship experience were the reference group comparing to the students with internship experience.

2.4. Results

2.4.1. Dependent Variable- Engineering Identity

Cronbach's alpha, an indicator of internal consistency, was 0.83 for four items comprising the engineering identity dependent variable, which is well within the acceptable range (Brace, Kemp, & Snelgar, 2012).

2.4.2 Independent Variables Instrument Development

2.4.2.1. Exploratory Factor Analysis for Engineering Identity Factors

After following EFA guidelines for item-to-factor loadings (Comrey & Lee, 2013) and content validity, the initial 34 items were reduced to 21 items, which loaded onto four factors. All items that had either low loadings onto a factor (less than 0.40) or significant cross-loadings across factors (higher than 0.32 on multiple factors) were eliminated (Field, 2009). The four-factor solution was chosen based on both the scree plot and the eigenvalue test. Table 2.1 shows the label, items, and EFA item factor loadings for each of the four factors. Each factor consists of at least three items. The four factors were identified and labeled based on the initial hypothesis and the items that composed each factor. The Cronbach's alpha values of all four factors are well above 0.70 as shown in Table 2.1, which is the acceptable standard.

2.4.2.2. Confirmatory Factor Analysis for Engineering Identity

A confirmatory factor analysis was conducted in order to validate the underlying structure of the scale based on information gathered from the EFA and the authors' knowledge of the theorized latent factors. Using the factors identified in the EFA, a fit a model containing the 4-factor solution was used. To assess a better fitting model, both face validity and modification indices were utilized to eliminate two items in the CFA procedure. The two items are "I feel good when I am doing engineering" and "my advisor expects me to continue my career as an engineer." The final number of items is 19 as shown in Table 2.1. The reliability for the theorized factors was 0.91 for engineering interest, 0.88 for engineering competence, 0.88 for engineering recognition, and 0.79 for interpersonal skills competence. The model fit indices were at an acceptable level (RMSEA = 0.06, CFI = 0.95, TFI = 0.94, and χ^2 =2022.05; df=171; p<0.001) (Kline, 2015).

Table 2.1. *EFA and CFA Results for Survey Measures of Engineering identity*

Factor	Survey Items	EFA Factor Loading	CFA Factor Loading
Engineering interest (α=0.91)	I like doing engineering	0.81	0.80
	I am interested in learning more about engineering	0.76	0.80
	In general, I find working on engineering projects interesting	0.76	0.78
	I enjoy engineering activities as part of my work week	0.76	0.84
	I think engineering is fun	0.76	0.66
	I am interested in my engineering work	0.73	0.81
	I feel good when I am doing engineering[1]	0.55	-
Engineering competence (α=0.88)	Creating prototypes to test an idea	0.96	0.81
	Designing a system, a part/component of a system, or a process based on realistic constraints	0.77	0.76
	Improving a design to make it more efficient (faster, better, cheaper)	0.73	0.69
	Designing and conducting experiments to test an idea or learn more about a system	0.63	0.81
	Identifying technical solutions that are as simple as possible	0.60	0.75
Engineering recognition (α= 0.88)	Other students in my program see me as an engineer	0.90	0.80
	My friends see me as an engineer	0.77	0.63
	My family sees me as an engineer	0.74	0.78
	My peers view me as an engineer	0.70	0.79
	My advisor sees me as an engineer	0.66	0.83
	My advisor expects me to continue my career as an engineer[1]	0.55	-
Interpersonal skills competence (α=0.79)	Communicating verbally, for example in discussion with others	0.85	0.78
	Presenting my professional work to others	0.78	0.80
	Communicating my ideas in writing I am interested in my research topic	0.52	0.70

Note: 1: Eliminated item for the CFA procedure; Cronbach's Alpha values stay same after eliminating item for CFA.

2.4.2.3. Pearson Correlation

The results of the correlation analysis are presented in Table 2.2. Students' intention to complete their engineering graduate degrees has a significant positive correlation with engineering identity ($r = .14$), engineering interest ($r = .17$), and engineering recognition ($r = .16$). Engineering graduate students' engineering identity is positively and significantly correlated with all four independent factors: engineering interest ($r = .70$), engineering recognition from others factor ($r = .66$), engineering competence ($r = .38$), and interpersonal skills competence ($r = .31$). Further, all four independent factors are positively and significantly correlated with each other, and the correlation range is between 0.21 and 0.64.

Table 2.2. *Correlation Table for Measures of Engineering Identity and Intention to Complete*

Scale	1	2	3	4	5
1. Intention to complete	1				
2. Engineering identity	.14*	1			
3. Engineering interest	.17**	.70**	1		
4. Engineering competence	.08	.38**	.36**	1	
5. Engineering recognition	.16**	.66**	.64**	.31**	1
6. Interpersonal skills competence	.08	.31**	.21**	.24**	.30**

Note: * $p<.05$; ** $p<.01$

2.4.2.3. Sequential Multiple Linear Regression Models: Predicting Engineering Identity

Table 2.3 presents three regression models to predict engineering identity. Model 1 shows that student characteristics explain just 1.4% of the variance in engineering identity. Model 2 introduces the three factors of academic engineering identity. These factors explain 57.9% of the variance in their engineering identity after excluding the 1.4% of 59.3% explained by control variables. There was a collective significant effect between the engineering interest, engineering competence, and engineering recognition, ($F(3, 274) = 132.41$, $p < .001$). Model 3 added the interpersonal skills competence variable as a part of engineering identity. The additional interpersonal skill competence factor was a significant factor and explains 2.5% of the variance in their engineering identity ($F(1, 273) = 8.32$, $p < .001$). The total final model explains 60.4% of the variance in engineering identity.

In Model 1, there are no significant predictors of engineering identity. In Model 2, all three engineering identity factors were significant: engineering interest ($b = 0.474$ with $p < 0.001$), engineering recognition ($b = 0.301$, $p < 0.001$), and engineering competence ($b = 0.118$, $p < 0.01$). The positive coefficients indicate that students who perceive they have higher engineering interest, greater engineering recognition from others, and higher engineering competence in their engineering graduate programs are more likely to have stronger engineering identities. After adding covariates in Model 2, two student characteristic variables significantly predict engineering identity. Bachelor's degree in engineering was a significant positive predictor ($b = 0.082$, $p < 0.05$) of engineering identity, meaning that graduate students who hold an engineering bachelor's degree are more likely to have higher engineering identity compared to engineering graduate students with a bachelor's degree in another field. In addition, mechanical engineering students ($b = -0.101$, $p < 0.05$) had weaker engineering identities compared to electrical/computer engineering students. In Model 3, newly added interpersonal skills competence variable ($b = 0.118$, $p < 0.01$) was a significant and positive predictor of engineering identity. All significant factors in Model 2 were also significant in Model 3.

Table 2.3. *Multiple regression models for Predicting Engineering Identity*

Variables	Model 1	Model 2	Model 3
Students' characteristics			
Female	-.032	.005	.010
International	-.030	.011	.040
Civil/Architectural	.030	.041	.029
Mechanical	-.066	-.101*	-.097*
Master's with thesis	.070	.056	.062
Master's without thesis	.095	.033	.034
B.S. degree in engineering	.090	.082*	.084*
Work experience	-.049	-.038	-.032
Internship	.108	.075	.068
Graduate students engineering identity			
Engineering interest		.474***	.476***
Engineering competence		.118**	.092*
Engineering recognition		.301***	.275***
Interpersonal skills competence			.118**
R^2	.014	.593***	.604***
ΔR^2	-	.579	.025
Δ F test		132.41***	8.32**

Note: $*p< .05$, $**p< .01$, and $***p< .001$.

2.5. Discussion

This study demonstrates that with adaptation, frameworks previously developed for measuring the engineering identity of undergraduates, apply to graduate students. The academic factors included in several prior studies, engineering interest, competence, and recognition from others, explain 58% of the variance in engineering identity of engineering graduate students (R^2=.58). This is more than twice the variance explained in similar models of engineering identity in undergraduate students (R^2=.27) (A.D. Patrick et al., 2018). In this study, engineering interest had the highest standardized coefficient, followed by engineering recognition from others and engineering competence. This ranking is similar to results from undergraduate engineering identity studies spanning first, second, third and fourth year students (Choe et al., in press; A.D. Patrick et al., 2018). In a study of first-generation, first-year engineering students, recognition was the strongest predictor of engineering identity (Verdin, Godwin, Krin, Benson, & Potvin, 2018). However, engineering masters' and doctoral students perceived engineering interest, competence, and recognition differently from engineering undergraduate students based on the items for each factor. Important adaptations are discussed below.

In this study, engineering interest was the strongest predictor of engineering identity. Students who have higher interest in engineering are more likely to have stronger identification as an engineer. While undergraduate items captured students interest in learning engineering and positive attitude toward engineering, graduate items additionally captured interest in engineering work. Unique items from the graduate engineering interest scale are "in general, I find working on engineering projects interesting," and "I enjoy engineering activities as part of my work week." In interviews, graduate students emphasized interest in doing engineering as well as learning about it.

Engineering recognition from others required the most adaptation for master's and doctoral students. In the pilot, limited changes to undergraduate engineering recognition items were made (A.D. Patrick et al., 2018), but recognition did not factor out in the initial EFA. Recognition did emerge in the second EFA, after adding several items about the advisor and peers, informed by interviews and consultation with expert reviewers. This study shows that recognition from advisor and graduate student peers were important. Similarly, holding an engineering bachelor's degree was also significant in the final model, which interviewees indicated was an important form of recognition as an engineer.

Engineering competence had the lowest beta among the three academic factors but was still a significant predictor for engineering identity. While most undergraduate items measured students' engineering competence and performance based on classroom settings (e.g., doing well on exams), graduate items measured competence level of more specific engineering skills such as designing, prototyping and finding solutions (A.D. Patrick, N. H. Choe, et al., 2017).

Further, interpersonal skills competence was important, with a higher coefficient than engineering competence in the final model. Graduate school requires a high level of communication skills which foster graduate students' engineering identities. These were identified in interviews as important to success as an engineer. This finding aligns with Choe et al. (in press), in that considering professional aspects of engineering (e.g., analysis, design, tinkering) improves prediction of engineering identity in undergraduates. Engineering identity studies on both engineering undergraduate and graduate students indicated the importance of professional aspects of engineering practice.

Finally, graduate students' engineering identity, engineering interest, and engineering recognition are all positively correlated with their intention to complete their engineering graduate degrees. When students' engineering identities increase, their intention to complete degrees increases. This is preliminary evidence that identity is worth investigating as a potential pathway to increasing retention in engineering graduate programs.

2.6. Conclusion

This study described development and adaptation of an engineering identity scale for engineering graduate students. The engineering identity scale contains four factors: engineering interest, engineering recognition from others, engineering competence, and interpersonal skills competence. In addition, all four factors were positive and significant predictors of engineering identity, explaining a particularly large proportion of the variance. This study lays the groundwork for future investigations and interventions to foster engineering graduate students' engineering identities and retention.

Chapter 3: Manuscript Two

Engineering Identity Development of International Graduate Students in the US

Abstract

Engineering identity has become a popular lens to understand academic performance, retention, and career choices of undergraduate and graduate engineering students. However, despite the high ratio (approximately 50%) of international graduate students in US engineering programs, less attention has been given to understanding the engineering identity of international students. This paper describes a quantitative survey study of engineering identity for engineering graduate students. T-tests and multiple linear regression models were used to explore the differences in engineering identity between US and non-US students. The main finding is that most of the engineering graduate identity constructs were significantly different between the US and non-US students, including research interest/recognition, disciplinary engineering recognition, math/science competence, disciplinary engineering competence, and interpersonal skills competence. This paper also presents three significant interactions between engineering graduate identity constructs and citizenship status. Differences in engineering education curricula is described as a potential explanation for these differences in engineering identity.

3.1. Introduction

The ratio of international to domestic students in graduate programs is high in many countries. For example, South Africa's doctoral programs had an enrollment of 40% international students in 2016 (Herman & Meki Kombe, 2019). In Canada, 28% of graduate students are international (Universities Canada, 2014). Further, over the past decade, graduate schools in several nations have increased their number of international students. For instance, the number of international graduate students in South Korea doubled from 2009 to 2017 (Korea, 2018). In addition, the Institute of International Education (2016) reported an influx of international graduate students to US graduate programs over the past two decades.

Among all academic disciplines in the United States, engineering graduate programs have a particularly high representation of international students compared to other disciplines (Institute of International Education, 2016). Yoder (2015) reported that engineering graduate programs have increased their inclusion of international members, including graduate students, exchange scholars, and faculty members. Importantly, approximately 50% of engineering graduate students in US research universities are international students (Yoder, 2015).

The high proportion of international students in engineering disciplines has recently become a topic of investigation within engineering education research (Crede & Borrego, 2014; Le & Gardner, 2010; Newberry, Austin, Lawson, Gorsuch, & Darwin, 2011; Park, Chuang, & Hald, 2018). The involvement of non-US students significantly influences the experiences of peers, faculty, and staff in engineering graduate programs (Park et al., 2017). Some studies suggest that institutions and advisors should consider non-US citizen students' cultural backgrounds and language proficiency and provide different advising approaches for students' academic success (Le & Gardner, 2010; Newberry et al., 2011). Identity is a way of promoting persistence in engineering at the undergraduate and graduate levels (Burt, 2014; Godwin et al., 2016; A.D. Patrick et al., 2018), so it is important to understand how identities of international students may differ from those of domestic students.

Identity has been a popular topic in the effort to understand engineering students' retention, academic performance, and career choices in engineering education. Gee's (2000) identity theory has been used to describe engineering identity in a number of prior studies (Choe et al., in press; Godwin et al., 2016; A.D. Patrick et al., 2018). Gee described identity as how an individual defines him- or herself as a “kind of person.” He also mentioned that identity means an individual belongs to and power comes from his or her position in the institution. In addition, an identity can be based in the recognition of others and explained as ascription or an achievement (Gee, 2000). Importantly, Pierrakos, Beam, Constantz, Johri, and Anderson (2009) reported that engineering students with stronger engineering identities would be expected to persist in engineering.

Considering the diverse learning environments of engineering research labs, graduate students’ engineering identities should be influenced by interactions among lab members from different backgrounds. Several researchers recently investigated engineering identities of engineering graduate students (Burt, 2014; Choe & Borrego, in press). Burt (2014) observed that engineering graduate students develop their identities through research experiences during their graduate programs. He explained that engineering identity development is influenced by several factors, including level of competence in engineering and research and collaborations with other research group members. Choe et al. (2017) also found that engineering identities of engineering graduate students are positively correlated with research competence, research interest, engineering competence, and engineering interest. Based on these studies, this study highlights how the competence and interest levels of engineering and research may influence engineering identity development of international and US engineering graduate students. Considering the high representation of international students in the US engineering graduate programs, it will be worthwhile to compare international and US students’ engineering identity, so they can be better advised and retained.

Research questions

1. Do US and non-US engineering graduate students differ in engineering identity and engineering graduate identity constructs?

2. What constructs of engineering graduate students' engineering graduate identity predict their engineering identities?
3. Do associations between engineering identity and engineering graduate identity constructs differ significantly between US and non-US students in engineering graduate programs?

3.2. Literature Review

3.3.1. Engineering Program Accreditation

Depending on the country in which they earned their undergraduate degree, engineering graduate students may have very different experiences and attitudes about important apects and skills in engineering. Different national and regional emphases may have important implications for what influences engineering identity.

The Accreditation Board for Engineering and Technology (ABET) is a US-based nongovernmental and major accreditation organization for engineering programs. In 2018, ABET accredited 3,080 four-year college engineering programs in the United States (ABET, 2019). ABET was established in 1932, and its engineering criteria are widely used in the US and other nations. ABET engineering accreditation criteria have significantly evolved to accommodate changing engineering skills. In 1995, ABET established new criteria to assess engineering programs called Engineering Criteria 2000 (EC2000). One of the criteria emphasized communication and teamwork skills in a collaborative situation, and many universities implemented those skills' development in their engineering curricula. Their efforts in developing communication and collaboration skills are reflected in engineering graduates. For instance, according to a 2004 survey, the majority of US engineering department chairs agreed that ABET EC2000 criteria helped engineering students increase learning outcomes, especially interpersonal communication, teamwork, technical writing, and verbal communication skills (Volkwein, Lattuca, Terenzini, Strauss, & Sukhbaatar, 2004).

Prior to ABET's adoption of EC2000 criteria, in 1989, the Washington Accord began to document international agreement regarding engineering accreditation. This agreement initially included six nations (Australia, Canada, Ireland, New Zealand, the United Kingdom, and the United States), but between 1995 and 2009, Hong Kong, Japan, Singapore, South Korea, Taiwan, Malaysia, and South Africa joined as well. In 2013, the Washington Accord announced 12 engineering graduate attribute profiles. Like the ABET engineering criteria, the 2013 Washington Accord included communication, teamwork skills, and leadership as vital features for engineers. In addition, engineers are viewed differently, and different engineering skills are emphasized in various countries. For example, France considers engineers to advance the society toward an ideal future; whereas, British engineers emphasize material comfort (Downey et al., 2006). Importantly, French engineers perceived that high mathematic competence allowed them to work in government positions, the highest-ranked jobs in France; otherwise, the majority of French engineers work in industry jobs, which are considered lower-status positions (Downey et al., 2006). Depending on when countries joined the Accord and their motivations for doing so, communication, teamwork skills, and leadership are emphasized differently in undergraduate engineering curricula.

3.3.2. International Graduate Students' English Proficiency and Identity Development in the United States

Communication and teamwork skills are also influenced by graduate students' comfort level with the language, which in turn influences their learning and development as graduate-level engineers. Studies in the field of English as a second language (Hsieh, 2006; Lee & Ciftci, 2014) explain that international students' English proficiency influences their academic development in several different ways, including disciplinary and knowledge acquisition, socialization, and demonstrating their scholarly work in various writing projects and assignments. They point out that a lack of English proficiency can hinder international students' abilities to learn hands-on knowledge in engineering labs that need to be acquired by communicating with senior lab members or faculty advisors. Ravichandran, Kretovics, Kirby, and Ghosh (2017) interviewed 15 international graduate students at US educational institutions whose first languages were not English. The authors reported that students who do not have English as their first language are less confident in their writing, speaking, and oral presentation abilities. In addition, English writing proficiency is an important factor in international students' efforts to produce quality scholarly works during their graduate programs.

English proficiency may also enhance or hinder international students' professional identities through writing. In the field of literacy, researchers have investigated the relationships between academic writing and students' identity development. Street, Makoul, Arora, and Epstein (2009) explained that academic writing involves the articulation of a situation and that text represents an author's method for communicating with others. In other words, writers use text to express their values, beliefs, and philosophies and to communicate them to others. Moje and Luke (2009) explained that this writing process shapes authors' identities as well as readers' identity development. Similarly, in the context of engineering education, international students' engineering identities can be influenced negatively by their incompetence in their English writing and verbal communication skills.

3.3. Methods

3.3.1. Survey Administration and Participants

Table 3.1. *Number of international student participants and percentage of three regions for three nationality categories.*

Asia (n= 108)			Other (n=16)			Middle East (n=11)		
Nationality	n	% in region	Nationality	n	% in region	Nationality	n	% in region
"Asian"	1	0.93%	Nigerian	1	6.30%	Egyptian	1	9.10%
Cambodian	1	0.93%	Argentinian	1	6.30%	Iranian	5	45.50%
China	33	30.56%	Brazilian	3	18.80%	Lebanese	3	27.30%
Filipino	2	1.85%	Canadian	2	12.50%	Pakistani	1	9.10%
India	46	42.59%	Colombian	1	6.30%	Serbian	1	9.10%
Japanese	1	0.93%	European	1	6.30%			
Malaysian	1	0.93%	Greek	1	6.30%			
South Korea	15	13.89%	Nigerian	1	6.30%			
Taiwanese	7	6.48%	Romanian	1	6.30%			
Vietnamese	1	0.93%	Turkish	4	25.00%			

I administered the survey via an online survey program Qualtrics to civil/environmental, electrical/computer and mechanical engineering graduate students at the same US institution. The surveys were distributed by the graduate coordinators of each department via one initial email survey invitation and three follow-up additional reminders. Respondents who completed the surveys were submitted into a drawing for one of six $50 gift cards.

In the survey, I asked respondents their gender, nationality, engineering discipline, graduate program, whether they obtained a bachelor's engineering degree, engineering work experience prior to current program, and internship experience during current program.

A total of 287 engineering graduate students who identified their nationalities completed the survey. Among participants, 131 were either US citizen or permanent resident, and 156 were non-US students. Majority of the non-US students' nationality is India (n=46), China (n=33), South Korea (n=15), and 21 non-US students did not provide their nationalities.

Table 3.1 shows the breakdown of nationalities with three categories: Asia, others, and Middle east. This descriptive analysis has similar proportion of nationality regions with Crede and

Borrego (2014) study conducted at four different US institutions.

Out of 287 respondents, 76 respondents identified as women, and 211 as men. In term of programs, 167 were enrolled in a doctoral program, 56 were in a thesis master's program, and 64 were in a non-thesis master's program. In terms of engineering discipline, 121 were electrical or computer engineering students (in the same department), 93 were civil or environmental engineering students (in the same department), and 73 were mechanical engineering students.

3.3.2. Survey Questions and Instrument

The survey consisted of eight demographic questions and 64 five-point Likert scale items measuring the independent variables (engineering graduate identity).

Independent variables: Constructs capturing the key factors affecting engineer identity and researcher identity were adapted from the undergraduate science and engineer identity model (Carlone & Johnson, 2007; Godwin, 2016b; Hazari et al., 2010; Prybutok et al., 2016). Based on the identity model, I expected that graduate students' engineering identities will be affected by three factors: disciplinary engineering competence/performance, disciplinary engineering interest, and recognition as an engineer by others. On the other hand, previous work on researcher identity does not provide a framework for measuring researcher identity. Therefore, I have adapted the engineer identity model to researcher identity. I expected that researcher identity is affected by three factors: research competence/performance, research interest, and recognition as a researcher by others. Additionally, I included interpersonal skill competence in the framework because interpersonal skill competence affects both engineering and researcher identity since these skills included are relevant to both identities. This began to emerge during the item generation phase when some items appeared to be equally relevant to both engineering and research.

The EFA was conducted to result in six factor solution which measure various engineering graduate identity constructs. The total of 64 items were reduced to 42 items from the EFA. I explain each variable in more detail and provide results of a measure of Cronbach's alpha as an indicator of internal consistency with each variable (see Table 3.2). All Cronbach's alpha values were higher than 0.80 considered good range (Brace et al., 2012). Each factor and label are described as following. Research interest measures the level of interest in exploring, learning and conducting research. Research recognition represents student perceptions of how others (e.g. advisor, peers, friends) view them as a researcher. Disciplinary engineering competence describes a student's perceptions of their own engineering abilities, knowledge, and skills relevant to engineering projects. Disciplinary engineering interest measures students' interest in learning about engineering and working on engineering projects. Math/science competence is a measurement of students' perception of their own math/science knowledge, skills, and abilities in their graduate program. Math/science knowledge is necessary to conduct research in most engineering disciplines. Disciplinary engineering recognition represents student perceptions of how others (e.g. advisor, peers, friends) view them as engineers. Interpersonal skills competence includes students' perception of their own collaboration and communication skills. The survey stem questions for measuring interest or recognition were "To what extend do you agree or disagree with the following statements?" and the stem questions for quantifying competence were "How competent are you with the following tasks?"

Dependent variable: A total of five items were borrowed from Plett et al. (2011) to measure engineering identity as a dependent variable. The EFA results in retaining four of the items with a 0.83 Cronbach's alpha measure of internal consistency. An example item is "Being an engineer is an important reflection of who I am."

3.3.3. Data Analysis

I conducted a descriptive analysis, *t*-tests, and multiple linear regression analysis in this study utilizing the Stata 14. I calculated means and standard deviations of engineering identity and engineering graduate identity constructs for US and non-US students. In addition, *t*-tests were used to compare the differences in these variables between US and non-US students. I conducted Levene's test for each variable to confirm the variances of US and non-US students are similar. If the tests indicated the variances were significantly different, I ran Welch's *t*-tests. Otherwise, I ran equal variance *t*-tests.

Table 3.2. *Cronbach's alpha and Number of Items for Engineering Graduate Identity Constructs*

Variables	Alpha	# of Items
Research Interest/ Recognition	0.96	14
Disciplinary Engineering Competence	0.83	3
Disciplinary Engineering Interest	0.87	5
Disciplinary Engineering Recognition	0.88	7
Math/science Competence	0.87	8
Interpersonal Skill Competence	0.81	5

Note: $^{*}p < .05$, $^{**}p < .01$, and $^{***}p < .001$.

Multiple linear regression models were used to predict the engineering identity of the graduate students. As a necessary step in creating multiple linear regression models, several control variables were used, which were dummy-coded. The reference group for these control variables are not listed in Table 3.3, so they are listed here as follows. For gender, male was the reference group. For nationality, US citizens were the reference group. For engineering discipline, electrical/computer engineering was the reference group. For the current degree program, Ph.D.

Table 3.3. *Mean, Standard Deviation (S.D.), and T-tests for Each Variable*

Variable		All students		US students		Non-US Students		Significance
		mean	S.D.	mean	S.D.	mean	S.D.	
Dependent	Engineering identity	4.19	0.68	4.20	0.69	4.18	0.65	n.s.
Independent	Research interest/recognition	3.93	0.85	3.82	0.97	4.02	0.73	0.04*
	Disciplinary engineering recognition	4.10	0.66	4.20	0.66	4.02	0.65	0.03*
	Math/science competence	3.83	0.64	3.70	0.62	3.93	0.63	0.00*
	Disciplinary engineering interest	4.32	0.63	4.36	0.60	4.28	0.66	n.s.
	Disciplinary engineering competence	3.68	0.84	3.51	0.92	3.81	0.74	0.00*
	Interpersonal skills competence	4.08	0.62	4.20	0.6	3.98	0.62	0.00*

Note: * *t*-test significant difference between US and Non-US student for each variable.

was the reference group. For receiving an engineering bachelor's degree, students who did not receive a bachelor's degree was the reference group. For work experience, students with no full-time work experience prior to entering their graduate program was the reference group. For internship experience, students with no internship experience was the reference group.

The regression analysis includes three models to predict engineering identity. In the first model, seven student characteristics were entered: gender, nationality, engineering discipline, current degree program, obtained engineering bachelor's degree, engineering work experience prior to graduate program, and internship experience during graduate program. In Model 2, engineering graduate identity scales were added: research interest/recognition, disciplinary engineering competence, disciplinary engineering interest, disciplinary engineering recognition, math/science competence, and interpersonal skills competence. In Model 3, interactions between the nationality variable and the six factors of engineering graduate identity were added.

3.4. Results

3.4.1. Descriptive Statistics and t-tests

Table 3.3 shows the descriptive statistics for the dependent and independent variables as well as the results of *t*-tests on these variables based on nationalities. Given the emphasis of nationality on outcomes in engineering, it was necessary to determine if there were any nationality differences in our sample. I found a nationality difference in the means of student's research interest/recognition, disciplinary engineering recognition, math/science competence, disciplinary engineering competence, and interpersonal skills competence. Whereas I found that the US and the non-US students have no significant difference in their engineering identity and disciplinary engineering interest (Table 3.1).

3.4.2 Multiple Linear Regression Models

Table 3.4 presents three regression models to predict engineering identity. Model 1 shows that student characteristics explain just 1.4% of the variance in engineering identity. Overall F test of model 1 was not significant $F\ (9{,}277) = 1.45$. Model 2 introduces the six factors of engineering graduate identity.

These factors explain 55.9% of the variance in their engineering graduate identity after excluding the 1.4% of 57.3% explained by student characteristics. There was a collective significant effect between the disciplinary engineering interest, disciplinary engineering competence, and disciplinary engineering recognition, $\Delta F\ (6, 271) = 61.54$, $p < .001$. Overall F test of model 2 was significant $F\ (15, 271) = 26.63$, $p < .001$. Model 3 added the six interaction terms as a part of engineering identity. Three of the additional factors were significant and explain 1.8% of the variance in engineering identity according to ΔF test ($\Delta F\ (6{,}265) = 2.95$, $p < .001$).

The total final model explains 59.1% of the variance in engineering identity and is a significant model according to the overall F test (F (21, 265) = 20.69, $p < .001$).

In Model 1, there are no significant predictors of engineering identity. In Model 2, among all six factors, three factors were significant: disciplinary engineering recognition ($\beta = 0.391$ with $p < 0.001$), disciplinary engineering interest ($\beta = 0.312$, $p < 0.001$), and interpersonal skill competence ($\beta = 0.125$, $p < 0.01$). The significant positive coefficients explain that students who perceive they have greater disciplinary engineering recognition from others, higher engineering interest, and higher disciplinary engineering competence are more likely to have stronger engineering identities. After adding covariates in Model 2, two student characteristic variables significantly predict engineering identity. Bachelor's degree in engineering was a significant positive predictor ($\beta = 0.103$, $p < 0.05$) of engineering identity, meaning that graduate students who hold an engineering bachelor's degree are more likely to have higher engineering identity compared to engineering graduate students with a bachelor's degree in another field. In addition, mechanical engineering students ($\beta = -0.094$, $p < 0.05$) had weaker engineering identities compared to electrical/computer engineering students in this sample.

In Model 3, among the six interaction terms, three were significant. Figures 3.1, 3.2, and 3.3 illustrate the three significant interactions. All significant engineering graduate identity factors in Model 2 were also significant in Model 3. Yet another student characteristic variable became a significantly predictor of engineering identity. Internship was a significant positive predictor ($\beta = 0.081$, $p < 0.05$) of engineering identity, meaning that graduate students who had internship experience during their graduate programs were more likely to have higher engineering identity compared to engineering graduate students with no internship experience during their graduate programs. Mechanical engineering variable became a non-significant predictor in Model 3.

The interaction between math/science competence and the citizenship variable is shown in Figure 3.1. When non-US students' math/science competence increased, their engineering identity also increased. There was no significant relationship between the US students' math/science competence and engineering identity. In the range of 1 to 3.2 of math/science competence level, US students had a significantly higher engineering identity than non-US students ($p < 0.05$). However, in the range between 4.1 to 5 of math/science competence level, non-US students had a significantly higher engineering identity than US students ($p < 0.05$). In other words, high math/science competence is a particularly strong predictor of engineering identity for non-US students, while math/science competence has no effect on the engineering identity of US students.

Figure 3.2 shows that disciplinary engineering interest was more strongly associated with engineering identity for US students than non-US students ($p < 0.05$). In the range of 1 to 3.8 of math/science competence level, US students had a significantly higher engineering identity than non-US students ($p < 0.05$). In other words, engineering interest was a strong, positive predictor of engineering identity for both groups, but it had a stronger effect for non-US students.

Table 3.4. *Multiple linear regression models of Engineering Identity predicted by Engineering Graduate Identity for Citizenship*

Variables	Model 1	Model 2	Model 3
Students' characteristics			
Female	-.032	.011	.030
Non-US citizenship	-.030	.034	.031
Civil/Architectural	.030	.020	.021
Mechanical	-.066	-.094*	-.081
Master's with thesis	.070	.060	.043
Master's without thesis	.095	.064	.085
B.S. degree in engineering	.090	.103*	.097*
Work experience	-.049	-.026	-.006
Internship	.108	.070	.081*
Engineering graduate identity			
Research interest/recognition		.067	.102
Disciplinary engineering Recognition		.391***	.408***
Math/science competence		.042	-.115
Disciplinary engineering interest		.312***	.413***
Disciplinary engineering competence		.072	.060
Interpersonal skills competence		.125**	.214**
Interactions			
Research interest/recognition x Non-US			-.057
Disciplinary engineering recognition x Non-US			-.032
Math/science competence x Non-US			.238**
Disciplinary engineering interest x Non-US			-.154*
Disciplinary engineering competence x Non-US			.053
Interpersonal skill competence x Non-US			-.144*
R^2	.014	.573	.591
ΔR^2	-	.559	.018
F test	1.45	26.63***	20.69***
Δ F test		61.54***	2.95**

Note: *$p < .05$, **$p < .01$, and ***$p < .001$.

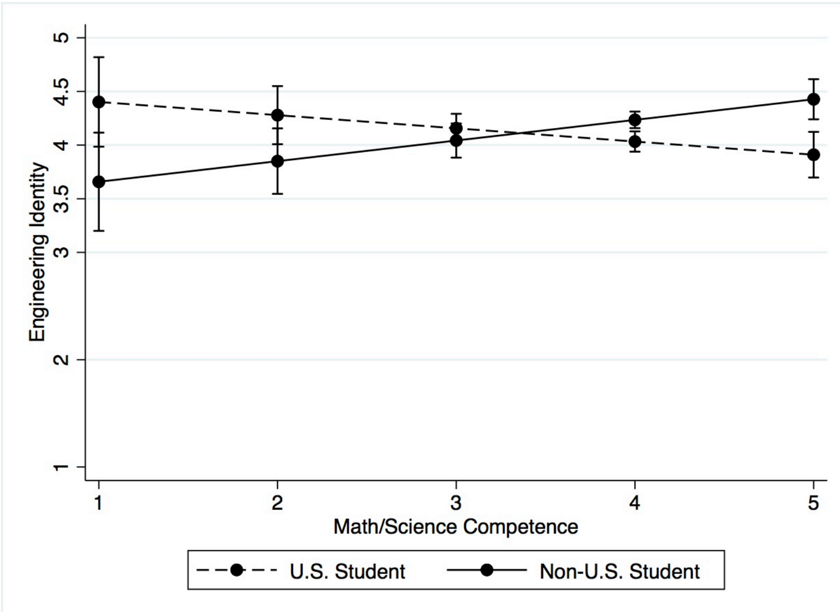

Figure 3.1. Interaction Plot for Engineering Identity and Math/Science Competence

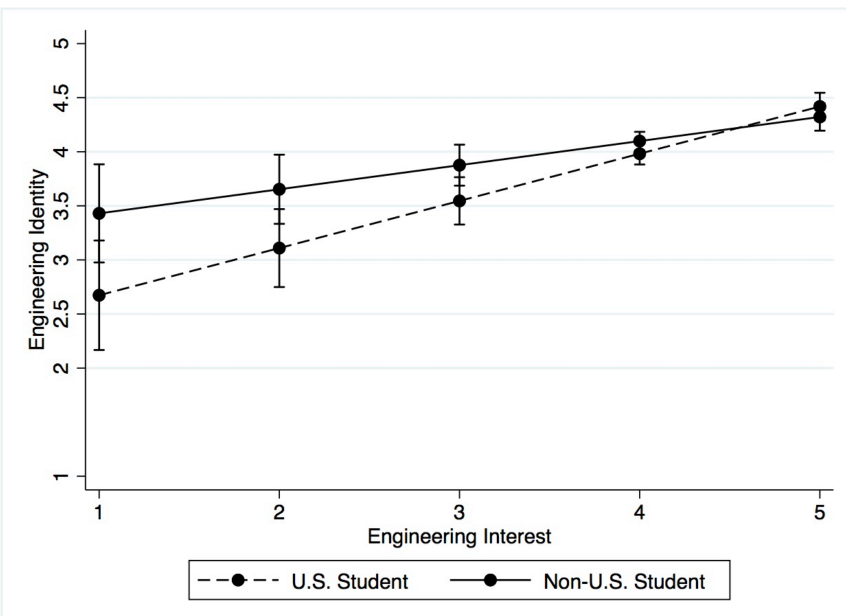

Figure 3.2. Interaction Plot for Engineering Identity and Engineering Interest

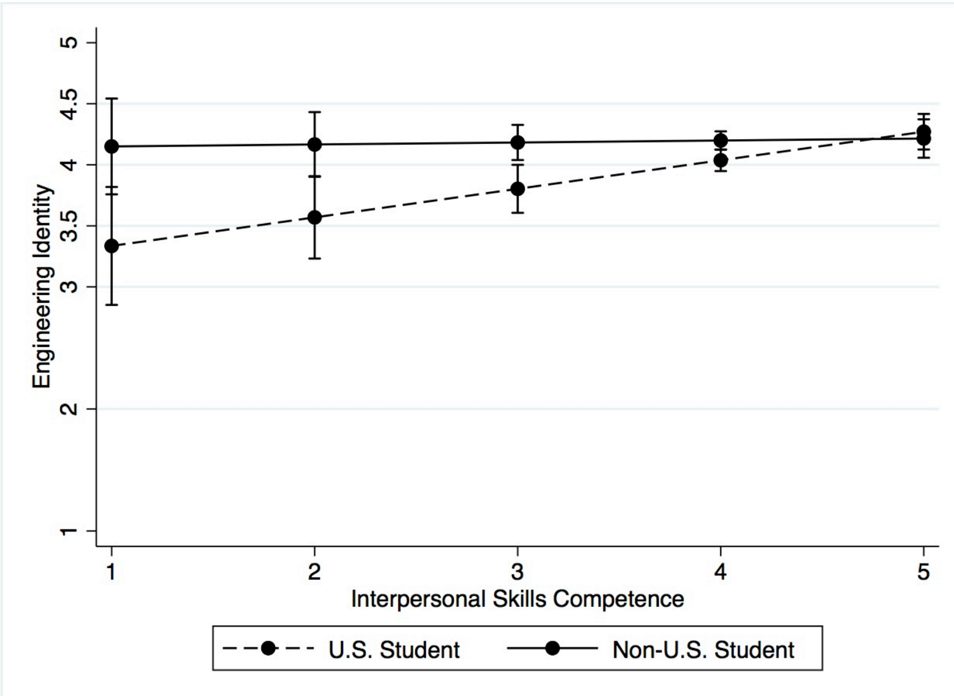

Figure 3.3. Interaction Plot for Engineering Identity and Interpersonal Skills Competence

The interaction between interpersonal skills competence and the nationality variable was shown in Figure 3.3. Figure 3.3 shows that US students' interpersonal skill competence was strongly associated with their engineering identity (p <. 05); however, non-US students' engineering identity was consistent at 4.1 out of 5 points despite different levels of interpersonal skill competence. Overall, non-US students had higher engineering identity levels compared to US students when interpersonal skill competence was in the range of 1 to 3.5. In other words, interpersonal skills confidence had no effect on the engineering identity of non-US students, while it was a positive predictor of engineering identity for US students.

3.5. Discussion

This study investigated the engineering identities of US and non-US engineering graduate students in the United States. The results show that the level of engineering identity is similar between US and non-US students; however, several constructs of engineering identity influenced the two groups of students' engineering identity differently. Four out of five engineering graduate identity constructs studied were significantly different for US and non-US students (Table 3.3). As Table 3.4 indicates, interactions between three graduate identity constructs and nationality significantly predict engineering identity. That is, three of the graduate identity constructs (math/science competence, engineering interest, and interpersonal skills competence) have different relationships with engineering identity for US and non-US graduate students. Understanding and considering these differences will help engineering graduate program staff to support both US and non-US students and foster their engineering identities. Consequently, those who have stronger engineering identities will more likely persist in engineering programs and fields.

The interaction with the highest coefficient was math and science competence level. Figure 3.1 shows that US students' engineering identities are not influenced by the level of math and science competence. However, non-US students' engineering identities are higher when their math and science competence level is higher. Non-US students may perceive math and science as more closely related to engineering to their educational backgrounds. However, US students may consider engineering to be more related to other aspects more recently emphasized by ABET such as contexts, ethics and problem-solving. Noting that math and science competence level is positively related to engineering identity for non-US students, staff can be aware of how their program's emphasis on math and science works to foster non-US students' engineering identities.

Engineering interest was the other interaction predictor of engineering identity for both US and non-US students. As shown in Figure 3.2, interest had a positive relationship with engineering identity, but the slope was higher for US students. Lack of engineering interest for US students, particularly at the lowest levels, may hinder development of their engineering identities. This result aligns with undergraduate study that engineering interest is a positive predictor of undergraduates' retention (A.D. Patrick et al., 2018). Considering that engineering identity is positively correlated with students' intentions to complete their degrees (Choe et al., 2017), it is important to help them keep their engineering interest high. For instance, graduate advisors and institutions should monitor US students' levels of engineering interests; in other words, they should check whether current engineering projects and classes satisfy students' interests. In our previous study, some doctoral students expressed that engineers with graduate degrees have more agency to pursue engineering work that relates to their interests compared to their undergraduate level of engineering work experience. Providing agency for engineering graduate students positively influences their satisfaction in their research groups and their intention to complete their graduate degrees (Borrego, Knight, & Choe, 2017). In addition, this study shows that providing students with an opportunity to participate in engineering work related to their interests helps them to foster their engineering identity. To attract prospective engineering graduate students, especially US students, institutions should provide curricula or programs in which students with a higher interest in engineering can engage.

Interpersonal skills competence is another significant interaction in which nationality predicts engineering identity. Figure 3.3 shows that non-US students' engineering identities are not influenced by the level of interpersonal skills competence. However, US students' interpersonal skills competence is positively correlated with their engineering identities. In the United States, ABET provided engineering degree accreditation and assured that interpersonal skills would be a part of engineering curricula and programs (ABET, 2017). This emphasis on interpersonal skills was included in 1995 in ABET accreditation and widely spread to most US institutions (ABET, 2019). Although the Washington Accord in 2003 included interpersonal skills with which engineers should be equipped, many Asian counties took several years to implement it. Asian nations such as India and South Korea were able to obtain international engineering accreditation by the Washington Accord between 2005 and 2007 (Jiaju, 2009), and China received full accreditation in 2016 (Ministry of Education of the People's Republic of China, 2018). Engineering students from these Asian nations may not consider interpersonal skills as essential as US engineering students do. On the other hand, US students may have stronger engineering identities when their interpersonal skills competence is higher. Given the importance of communication skills emphasized more recently in Asian nations' accreditation and English proficiency's relationship to productive scholarly works, the universities can provide English writing support programs for non-US students who do not speak or write English as their first language to help improve their writing skills. In addition, through the seminars or group research meetings, faculty members and advisors can provide opportunities to develop students' public speech and verbal communication skills.

3.6. Limitations

There are a few limitations in this study. First, I collected survey data from one large public research institution and within three engineering disciplines. Thus, the results of this study may not be generalizable to other US institutions. Second, I did not collect information on where students earned their engineering undergraduate degrees. I assumed that most non-US students in this study had obtained their engineering bachelor's degrees in their own countries and concluded that those undergraduate engineering programs had influenced the students' engineering identities. Similarly, I did not ask students about their English proficiency. The sample size was not large enough to categorize non-US students by country or region for analysis purposes.

3.7. Conclusion and Future Work

This study confirmed the high level (4.2 out of 5 points) of engineering identity for both US and non-US engineering graduate students. It is expected that students who have strong engineering identities would apply and continue their graduate degrees in engineering. Whatever their nationalities, the students I surveyed have high engineering identities overall. In this sample, the level of engineering graduate identity constructs was significantly different between US and non-US graduate students. In other words, their understanding of who engineers are, what engineers does, how engineers work, and what engineers are interested in varied between US and non-US students despite both groups having high engineering identity. The results indicated that engineering identity is shaped differently for US and non-US students, and a reason for that may be differences in their engineering curricula.

Engineering staff should understand different students' various ways of developing their engineering identities, particularly as it pertains to US and non-US students. This knowledge will help educators provide effective advice and keep students in the graduate programs. Further investigation is needed how graduate students' engineering identity can relate to academic performance and satisfaction with their degree programs.

Chapter 4: Manuscript Three

Master's and Doctoral Engineering Students' Interest in Industry, Academia and Government Careers

Abstract

Graduate education literature tends to focus on faculty careers. However, availability of faculty positions is declining, and more than one-third of US engineering doctorates enter industry. The purpose is to understand engineering graduate students' interest in industry, academia, and government careers, as it relates to their graduate engineering identities. A total of 320 engineering master's and doctoral students completed a survey about their graduate engineering identities and career paths. I created multiple linear regression models to predict students' likelihood of pursuing careers in industry, academia, and government. Then, I used cluster analysis to understand how and whether students are considering multiple options. Finally, I created multinomial logistic regression models to predict students' likelihood of being in one cluster versus another. Overall, higher research interest/recognition and math/science competence were related to greater likelihood of pursuing academia or government, while higher engineering disciplinary interest and recognition were related to greater likelihood of pursuing industry. Student nationality, degree program, and internship experience also distinguished students' likelihood of pursuing different career paths. Cluster analysis yielded three career path profiles: prefer industry, prefer academia, and open to all career options. Few students were considering academic careers exclusively. Engineering graduate students were considering multiple career paths; advisors and education researchers may need to catch up by shifting focus away from academic career preparation. Future work may explore when or how graduate

students associate research, math and science with academia and government and engineering with industry, and whether this is appropriate for career preparation.

4.1. Introduction

Several researchers have addressed that when individuals join engineering PhD programs, they have an underlying motivation to get jobs in academia (Austin, 2010; Roach & Sauermann, 2010; Thiry, Laursen, & Liston, 2007). Fiegener (2010) reported that, among engineering doctoral degree recipients in past decades, approximately equal proportions committed to careers in academia—about 45% (including postdoc positions)—while 38% opted to go into industry upon their graduation; the remaining 17% chose other positions.

However, according to a report from Larson, Ghaffarzadegan, and Xue (2014), approximately 13% of engineering PhD graduates (US citizen or permanent resident only) ended up getting academic jobs. They stated that while the total number of engineering doctoral recipients increased by approximately 70% from 2003 to 2013 (National Science Foundation, 2014), the growth rate of the number of academic positions is slower. This report also aligns with the Survey of Earned Doctorates (SED) data, which shows that US citizen PhD engineering students' commitment to academic positions reduced from 16% in 2004 to 12% in 2009. Further, Thiry et al. (2007) claimed that STEM graduate students are not welcomed to discuss careers paths other than academia with their faculty members. They reported that engineering graduate department faculty members have interest in grooming their students only for faculty positions. Further, Thiry and colleagues asserted that graduates who don't get academic jobs feel shame because of an underlying assumption that engineering PhD graduates will get faculty positions. However, the reality is that the majority of PhD graduates get industry jobs.

According to these phenomena, several researchers have paid attention to engineering doctoral students' career trajectories. For example, Mosyjowski, Daly, Peters, Skerlos, and Baker (2017) investigated the relationship between engineering doctoral students' academic utility value and their different career plans. They reported that returning doctoral students who set their sights on working in academia and government are more likely to show higher interest in conducting research as a part of academic interest during their PhD training.

Roach and Sauermann (2010) investigated engineering and science PhD students' career choices and showed that there are three aspects that they consider when deciding on their careers: their preferences for particular job attributes, expected role and tasks, and perceptions of each career position's availabilities. Litzler, Lange, and Brainard (2005) found that engineering graduate students who have a positive relationship with their advisors and who relate to their advisors as mentors were more likely to commit to careers in engineering fields.

Finally, engineering identity framework was utilized to understand engineering students' career intentions in engineering fields (A.D. Patrick et al., 2018; Tendhar, Singh, & Jones, 2018). Tendhar et al. (2018) addressed that engineering identity framework can be a way to investigate the career decision-making process for undergraduate engineering identity.

In sum, due to the gap between the availability of academic jobs and PhD graduates who want to get academic engineering jobs, it is important to understand possible other career paths and how students make decisions regarding their possible career choices.

In the current study, we investigated what doctoral engineering student characteristics and components of engineering identity predict their career aspirations toward industry, academia, and government. In addition, we included thesis master's and nonthesis master's students to compare with engineering doctoral students. The research questions that guided the study are as follows:

1. What student characteristics and components of engineering graduate identity predict engineering graduate students' career paths toward industry, academia and government?
2. What are the characteristic profiles of how engineering graduate students are considering the relative likelihood of careers in industry, academia, and government?
3. What student characteristics and components of engineering graduate identity predict these characteristic profiles of engineering graduate students' career paths?

This study extends prior work in multiple ways. First, it considers industry, academia and government career paths equally, and it includes thesis master's and non-thesis master's students alongside doctoral students. Second, it extends engineering identity frameworks to the graduate level and develops quantitative measures of several aspects of engineering graduate identity. Finally, it adds cluster analysis to create profiles of how and whether students are considering multiple career paths simultaneously.

4.2. Theoretical Framework

According to Gee's (2000) multiple identity theory, an individual holds or develops their multiple types of identities which connect to their performances in society. This includes academic, professional, and personal aspects of identity. Studies of undergraduate engineering identity have demonstrated relationships between engineering identity and retention in engineering (A.D. Patrick et al., 2018; Tendhar et al., 2018) and science and math identity and pursuit of an engineering major (Godwin et al., 2016). I argue that Gee's multiple identity theory may be particularly useful for understanding how graduate students navigate their many roles and responsibilities, and how these relate to preferences for a career in industry, academia, or government. Although prior studies on graduate engineering identity inform this work and are cited herein, a relatively new direction for graduate identity is extricating different academic and professional aspects of engineering identity. Our framework, as described below, is informed by the literature, interviews with graduate students and alumni, and factor analysis of pilot survey data.

One of the most widely used models for quantitative studies of undergraduate engineering identity posits that engineering identity comprises three constructs: engineering performance/competence, engineering interest, and recognition as an engineer by others (Carlone & Johnson, 2007; Godwin, 2016a; Hazari et al., 2010; A.D. Patrick et al., 2018). Performance/competence refers to belief in one's ability to perform engineering tasks and understand engineering concepts. Interest reflects one's desire to learn more about engineering, participate in engineering activities, and pursue engineering careers. Recognition means being recognized by others (e.g., faculty, friends, and family) as an engineer. It is reasonable to expect that since many engineering graduate students hold bachelor's degrees in engineering that the constructs would transfer to the graduate level. Two independent studies have confirmed this is indeed the case for independent samples of engineering graduate students at different US institutions (Choe & Borrego, in press; Perkins et al., 2018). However, simply adapting academic aspects of engineering identity from the undergraduate to graduate level is not inclusive of the many professional roles and associated identities of engineering graduate students, particularly as they consider careers in industry, academia and government.

4.2.1. Research During Graduate Study

Engineering graduate programs are designed to educate students to use research to produce marketable products and peer-reviewed research papers (Carlin & Denecke, 2008). Most students are required to complete a thesis or dissertation to demonstrate independent research skills (Crede & Borrego, 2012; Rogers & Goktas, 2010). It is common for engineering graduate students to participate in research projects with faculty members in a research group that is based on common interests (Carlin & Denecke, 2008). Through participation in these projects, engineering graduate students develop research skills such as generating ideas, conducting experiments, analyzing data, collaborating with others, and communicating results (Saddler, 2009).

However, not all engineering master's students in the United States are required to complete thesis research, and there is limited information on the proportion of students enrolled in thesis versus non-thesis engineering master's programs. The Council of Graduate Schools (Allum, Kirby, Sowell, & Gonzales, 2013) reports that among STEM master's programs at 5 institutions, 69% of degree programs required a thesis, noting that non-thesis options tend to be "professionally oriented" in a variety of disciplines other than engineering. Whether master's students are completing a thesis is an important control variable in the current study. Nonetheless, research is an important aspect of the training of many engineering graduate students.

4.2.2. Research Identity

Several prior studies suggest that engineering graduate students develop a research identity alongside their disciplinary engineering identity. Park's (2017) longitudinal qualitative study of counseling doctoral students found that graduate students develop both a disciplinary and a research identity. Hall and Burns (2009) argued that identification as a researcher is a big part of graduate identity. This study focused on how engineering graduate students develop a distinct identity as a researcher apart from any disciplinary identity as an engineer. Svyantek and

McNair (2015) described the multiple professional identities that engineering doctoral students develop during their programs, including research and teaching. Rogers and Goktas (2010) reported that engineering graduate students develop their research knowledge and skills over the years, and those skills are highly related to their academic performance. Burt (2014) observed that engineering graduate students develop their identities through research experiences during their graduate programs, finding that that engineering students' disciplinary identity development is influenced by several factors including level of competence in engineering and research, and collaborations with other research group members.

Other prior studies strongly suggest that the framework of performance/competence, interest and recognition may apply to research identity as well as engineering identity. According to Richardson (2006), graduate students' research identity can be developed in two ways: performing as a researcher and being recognized as a researcher. Svyantek, Kajfez, and McNair (2015) explained that one result of having a strong research identity is demonstrating specific research skills in the discipline. Maura Borrego, Knight, Gibbs Jr, and Crede (2018) found that engineering undergraduates with higher research self-efficacy (similar to research performance/competence) were more likely to express interest in graduate study. Corte and Levine (2002) argued that research identity is highly related to one's research interests. Indeed, two independent prior studies present evidence that performance/competence, interest and recognition related to research are relevant factors in studying engineering graduate student identity (Choe et al., 2017; Perkins et al., 2018). In one of these studies, Perkins et al.'s (2018) separate exploratory factor analysis (EFA) on research-related items only yields factors for performance/competence, interest and recognition. In our own prior work, I ran a combined EFA of engineering disciplinary and research items, which yielded additional an additional factor that I named math and science competence (Choe et al., 2017).

4.2.3. Math and Science Competence

In our work developing and piloting the survey for the current study, I interviewed graduate students, faculty members, and practicing engineers with graduate degrees to develop detailed items to address both engineering and research competence, interest and recognition. During exploratory factor analysis, some of the items originally developed to address research and engineering competence separately were grouped into a single factor, which I named math/science competence (Choe et al., 2017). This included items such as "understanding and applying scientific and mathematical relationships based on the conditions" and "applying math and science concepts to make new systems/models." The emergence of this distinct construct is not unexpected, given the emphasis of math and science as foundational to engineering (e.g., ABET, 2017). Math and science performance/competence has previously been linked to engineering major choice among undergraduates (Godwin et al., 2016), and Ro, Lattuca, and Alcott (2017) found that math proficiency is an important factor predicting engineering undergraduate student intent to pursue graduate study.

4.2.4. Professional Skills Competence

A final construct in our model of engineering graduate student identity is professional skills competence. In the interviews I used to develop the current survey, skills such as collaboration and communication were cited several times, but as relevant to success in both research and engineer roles. I created items to address professional skills competence specifically, and found that at least some of these items factored separately from engineering and research competence items (Choe et al., 2017). Rogers and Goktas (2010) addressed that engineering graduate students perceived that communication skills both oral and written are important components to conduct their research work. Prior work has developed a scale to measure affect toward professional aspects of engineering identity among undergraduates (Anita D. Patrick et al., 2017) and has found that this professional scale improves prediction of engineering identity over models considering only the academic aspects of engineering performance/competence, interest and recognition (Choe et al., in press).

4.2.5. Summary

In summary, our theoretical framework for predicting engineering graduate students' interest in industry, academic and government career paths is based on their multiple professional role identities. Specifically, I argue that engineering graduate identity comprises engineering disciplinary competence, interest, and recognition; research competence, interest, recognition; math and science competence; and professional skills competence. In this paper, I refer to these aspects—including academic, professional, disciplinary, and research identity—collectively as *engineering graduate identity*.

4.3. Methods

4.3.1. Overview

I surveyed 320 engineering doctoral, thesis master's and non-thesis master's students about their graduate engineering identities, personal characteristics, and interest in careers in industry, academia and government. I used student characteristics items and identity factors to predict interest in industry, academia and government separately. Then, I used cluster analysis to create groups of students who were considering multiple options in similar ways. Finally, I created a second series of regression models using characteristics and identity constructs to predict cluster membership.

4.3.2. Participants

Participants were engineering graduate students at a large, research extensive, public university in the southwestern United States. The final sample included 320 students. For gender, 207 (65%) men, 76 (24%) women, and 37 (12%) prefer to not answer. Of the final sample, 183 (57%) were doctoral students, 66 (21%) were thesis master's, and 71 (22%) were non-thesis master's. Of 320 students, 131 students identified as domestic students, 156 students identified as international students, and 33 preferred not to answer regarding nationality. Of the final sample, 135 (42%) were electrical and computer engineering, 105 (33%) were civil or environmental engineering, and 80 (25%) were mechanical engineering. Cluster analyses used all 320 responses. Regression models were based on 281 observations because 33 students did not respond regarding nationality, and an additional six students did not respond to one of the independent variable items identity constructs.

4.3.3. Measures

I generated and adapted a total of 74 items from previous research: 67 main 5-point Likert-scale items measuring independent and dependent variables and seven students' characteristics questions.

4.3.3.1. Dependent Variables

I used three items to measure engineering graduate students' likelihood of pursuing careers in industry, academia or government. The stem read, "How likely are you to pursue each of the following career options after graduation?" I worded the industry item as "profit sector (industry) engineer," the academia item as "college professor/postdoctoral researcher," and the government item as “government engineer, e.g., at a national lab.” Participants responded on 5-point Likert-type scales in which 1 corresponds to “definitely no” and 5 to “definitely yes.”

4.3.3.2. Independent Variables

To capture student characteristics, I asked participants their gender, nationality, engineering discipline, degree program (master's without thesis, master's with thesis, or PhD), whether they held an engineering bachelor's degree, and details of work experience in engineering prior to graduate study as well as internship experience during graduate study.

The remaining 42 items measured engineering graduate identity constructs. Table 4.1 lists the six factors, the number of items comprising each factor, internal consistency measured by Cronbach's Alpha, and an example item. All Cronbach’s Alpha values are larger than 0.80, which indicates each factor is within the desirable internal consistency range (Brace et al., 2012).

To develop these items, I used the following procedures. I borrowed and adapted disciplinary engineering identity items from Godwin (2016a) and Prybutok et al. (2016) and research interest, recognition, and competence items from Bieschke, Bishop, and Garcia (1996). Interviews with graduate students, faculty members and practicing engineers with graduate degrees informed our adaptation, as well as expert review of items by engineering education researchers, graduate students and PhD engineers. In previous work, I piloted these items with engineering graduate students, submitting their responses to exploratory factor analyses (Choe et al., 2017). I then revised some items as described in detail below and ran a second round of EFA on the current data. For both rounds of EFA, I used the Principal Axis Factoring (PAF) extraction method and Oblique (non-orthogonal) rotation. PAF is appropriate for relatively simple factor patterns and interpretations (Loewen & Gonulal, 2015). I conducted Oblique (non-orthogonal) rotation since the factors could be inter-correlated with each other (Velicer & Jackson, 1990). I eliminated items with either significant cross-loadings higher than 0.32 on multiple factors or initially low factor loadings of less than 0.40. Based on considerations of face validity and internal consistency of factors, I raised the final factor loading cutoff to 0.45 for all items (Field, 2009). A total of 64 items was reduced to 42 items in the current study after several iterations of EFA yielded a six factor solution (see Appendix B) (Child, 1990; Field, 2009).

Specific changes to items based on EFA of pilot survey data are as follows. In the pilot study EFA (Choe et al., 2017), none of the engineering or research recognition items emerged as a factor (separately or combined). I believe this is because they were based on items originally written for first-year undergraduates that focus on family members and instructors and were adapted to focus on faculty advisors and peers. I added items to include recognition by family, friends and "other students in my program" as well as having an engineering undergraduate degree (this item was specific to engineering recognition). These resulted in a separate disciplinary engineering recognition factor and a combined research interest and recognition factor in the current analysis (Table 4.1).

Based on the items, I labelled and described each factor as follows. *Research Interest/Recognition* includes two aspects: research interest and research recognition. Research interest describes the interest level of graduate students in research topics, as well as their interest in learning about and working on research. Research recognition from others presents engineering graduate students' perceptions of how others (e.g., advisor, peers, friends, family members) acknowledge their research identity. *Disciplinary Engineering Competence* captures engineering graduate students' perceptions of their engineering abilities, knowledge, and skills relevant to engineering projects. *Disciplinary Engineering Interest* comprises engineering graduate students' interest in working on and learning about engineering. *Disciplinary Engineering Recognition* captures engineering graduate students' perceptions of how others (e.g., advisor, peers, friends, family members) acknowledge their professional engineering work. *Math/Science Competence* captures engineering graduate students' perception on the level of their mathematics/science knowledge and skills in their graduate program. Math/science knowledge and skills are required both to conduct research and complete engineering projects. *Professional Skills Competence* includes graduate students' perception of their communication and collaboration knowledge, skills, and abilities. The survey stems for the items measuring competence were "How competent are you with the following tasks?" and those measuring interest or recognition were "To what extent do you disagree or agree with the following statements?"

Table 4.1. Cronbach's Alpha, Number of Items, and Example Items for Scales Measuring Independent Variables

Variables	Alpha	# of Items	Example item
Research Interest/ Recognition	0.96	14	My advisor sees me as a researcher
Disciplinary Engineering Competence	0.83	3	Building and testing systems to learn more about how they work
Disciplinary Engineering Interest	0.87	5	I think engineering is interesting
Disciplinary Engineering Recognition	0.88	7	Other students in my program see me as an engineer
Math/science Competence	0.87	8	Understanding and applying scientific and mathematical relationships based on the conditions

Professional Skills Competence	0.81	5	Communicating verbally, for example in discussion with others

4.3.4. Data Collection

Graduate coordinators in electrical and computer, civil and environmental, and mechanical engineering distributed an email survey invitation to all current graduate students in these programs. The graduate students responded to surveys via an online survey application, Qualtrics. Each graduate coordinator sent three email invitations or reminders over several weeks during spring semester 2018. Participants who participated the survey were entered into a drawing for one of five $50 gift cards. The online survey form began with informed consent. Marking “yes” on the consent form allowed the participant to proceed to the survey.

4.3.5. Data Analysis: Linear Regression Models

I utilized IBM SPSS® 24 for exploratory factor analysis and cluster analysis and Stata Statistical Software: Release 15 for all other analyses. To address research question 1, I created three sets of sequential multiple linear regression models to identify which students’ characteristics and independent variables significantly predicted the three dependent variables of engineering graduate students’ likelihood of pursuing careers in industry, academia, and government.

Prior to the regression analysis, I conducted several tests of linear regression assumptions such as normality, linearity, and homoscedasticity. I used histograms, scatter plots, and Q-Q plots to confirm these assumptions were met. Variance Inflation Factors (VIF) confirmed that there is no multicollinearity issue in these regression models. I also conducted bivariate correlation to find correlation among independent and dependent variables (see Table 4.2).

Each regression analysis included the same two steps to predict each of the dependent variables. In the first step, I ran a baseline model of student characteristics including gender, nationality, engineering discipline (electrical/computer, civil/environmental, and mechanical engineering), current degree program (PhD, thesis master's, and non-thesis master's), obtained bachelor's degree in engineering degree, work experience in engineering field prior to graduate study, and internship experience during graduate study. In the second step, I added the six engineering graduate identity factors from Table 4.3 in a combined model.

I dummy-coded all students characteristics variables to convert categorical variables to be dichotomous. For gender, the reference group was male. For nationality, domestic students (US citizen or permanent resident) was the reference group for international students. For obtained bachelor's degree in engineering, students without the degree were the reference group for comparison with students who hold an engineering bachelor's degree. For engineering work experience prior to graduate program, students without work experience were the reference group for comparison with students who had work experience. For internship experience during their graduate programs, students without internship experience were the reference group for comparison with students who had internship experience. Engineering discipline was dummy-coded with three categories, and electrical and computer engineering was the reference for comparison with civil and environmental engineering and mechanical engineering. Engineering graduate program was also dummy-coded with three categories, and Ph.D. was the reference for comparison with thesis master's and non-thesis master's.

4.3.6. Data Analysis: Cluster Analysis

To answer research question 2, I conducted a two-step cluster analysis. While some engineering graduate students may consider only one career path, it is more reasonable to expect that some students are preparing for multiple paths (Reis, 1997). To more accurately describe the different focus of career planning for engineering graduate students, I created several clusters of students who have similar likelihood of future careers in industry, academia and government. Cluster analysis is a way to assign participants to a specific classification based on their pattern of dependent variables (Norušis, 2012). In other words, cluster analysis is a useful method for identifying homogenous groups of participants, cases, or observations named clusters (Sarstedt & Mooi, 2014). The goal of cluster analysis is to identify groups of individual participants that are related to one another and unrelated to individual participants in other groups (Norušis, 2012). In this study, I wanted to identify some clusters that group students with similar likely career paths to each other and different likely career paths from other students. In the cluster analysis, I included three different likelihood of careers in industry, academia, and government variables. Among several different types of cluster analysis, I conducted two-step cluster analysis over k-means or hierarchical clustering because I were exploring the number of clusters, and the three variables have categorical characteristics. Three categorical career variables were multinomial distributed that met the assumption of two-step cluster analysis (Sarstedt & Mooi, 2014).

IBM® SPSS Statistics finds the optimal number of clusters. In this study, the suggested optimal number of cluster solution was a three-cluster solution. The optimal number of clusters is determined by Bayesian Information Criterion (BIC) value. Fraley and Raftery (1999) described that BIC value is the ratio of the changes in the distance at each merge. An estimate of the number of clusters is obtained at the step where a large jump in the BIC value is observed (Chiu, Fang, Chen, Wang, & Jeris, 2001).

Among various ways to measure the overall goodness-of-fit measure of a cluster solution, two-step clustering Silhouette coefficient measure of cohesion and separation are conducted. The measure is based on the average distance between objects. It measures whether the elements within a cluster are similar to each other and each cluster different to the other cluster(s). In other words, silhouette coefficient indicated whether the students' career path in industry, academia, or government are well grouped within one cluster, and the cluster is different from other cluster(s). The measurement ranges are between -1 and 1. In a good solution, the distances within in a cluster are small and the distances between clusters are large, resulting in a silhouette coefficient value close to the 1. The silhouette coefficient less than 0.20 is a poor, and the measure between 0.20 and 0.50 is a fair, while the values of more than 0.50 is a good (Sarstedt & Mooi, 2014). In this study, the silhouette measure was .25 which is in fair range of cluster quality.

4.3.7. Data Analysis: Multinomial Logistic Regression Models

To answer research question 3, I ran a multinomial logistic regression used to predict a nominal dependent variable given students' characteristics and independent variables. In this study, results of cluster analysis were used as the dependent variable, and one cluster was a reference group to the other two clusters. Since the clusters were mutually exclusive, multinomial logistic regression predicts the odds of a student being in one cluster versus another. Total three multinomial logistic regressions were conducted with two models. Engineering graduate students' characteristics variables were entered into the first model block and the components of engineering identity and research identity independent variables were added to predict the student membership in one of the three clusters of the dependent variable in the second model block.

4.4. Results

4.4.1. Bivariate Correlation

I calculated bivariate correlations to investigate relationships between likelihood of career paths and the independent variables assessing graduate students' identity. The results of the correlation analysis are presented in Table 4.2. The significant level of correlation is $\alpha = 0.05$. Likelihood of pursuing a career in industry is positively and significantly correlated with disciplinary engineering recognition from others ($r = .19$), disciplinary engineering interest ($r = .14$), disciplinary engineering competence ($r = .16$), and professional skills competence ($r = .11$). Likelihood of pursuing career in academia is positively correlated with research interest/recognition ($r = .44$) and math/science competence ($r = .27$). Similarly, likelihood of pursuing career in government is positively correlated with research interest/recognition ($r = .28$) and math/science competence ($r = .16$). This correlation matrix (Table 4.2) indicates that each identity factor is correlated with at least one of the three dependent variables. Thus, I included all six independent variables as predictors in the regression models.

In the results of correlation between dependent variables, likelihood of pursuing a career in industry has a significant negative correlation with likelihood of pursuing career in academia ($r = -.25$). There was a positive and significant correlation between likelihood of pursuing career in academia and government ($r = .33$). There was no significant correlation between government and industry.

Table 4.2. *Bivariate Correlation between Dependent and Independent Variables*

Variables	1	2	3	4	5	6	7	8	mean	S.D.
1. Career in Industry	1								3.97	.98
2. Career in Academic	-.25*	1							3.11	1.26
3. Career in Government	-.03	.33*	1						3.15	1.08
4. Research Interest/Recognition	-.10	.44*	.28*	1					3.93	.85
5. Disciplinary Engineering Recognition	.19*	-.02	-.06	.37*	1				4.11	.66
6. Math/science Competence	.07	.27*	.16*	.46*	.33*	1			3.81	.64
7. Disciplinary Engineering Interest	.14*	.01	.07	.41*	.52*	.35*	1		4.32	.63
8. Disciplinary Engineering Competence	.16*	.01	.06	.38*	.24*	.46*	.28*	1	3.64	.84
9. Professional Skills Competence	.11*	-.06	-.07	.13*	.39*	.37*	.18*	.16*	4.06	.62

Note: *$p < .05$. S.D. abbreviates standard deviation.

4.4.2. Multiple Linear Regression Models

Table 4.3 presents the regression models for predicting graduate students' likelihood of pursuing careers in industry, academia, and government. For the first two columns predicting industry, Model 1 shows that graduate student characteristics explain 6.2% of the variance in likelihood of pursuing a career in industry. Master's without thesis (as compared with PhD) was a positive predictor ($\beta = .196$, $p < .01$) of pursuing a career in industry. Having an internship during graduate study ($\beta = .151$, $p < .01$) also significantly predicted pursuing a career in industry, while being female was a negative predictor ($\beta = -.126$, $p < .05$). In Model 2, I added the six independent variables of the graduate identity scale. A total of 12.2% of variance was explained by Model 2. Identity scale explained an additional 6% of variance in pursuing career in industry. In this model, among the six independent variables, Research interest/recognition ($\beta = -.300$, $p < .001$) was a significant negative predictor and disciplinary engineering recognition ($\beta =$

.186, $p < .05$) a significant positive predictor of pursuing career in industry. Among student characteristics variables, being an international student ($\beta = .136$, $p < .05$), having had an internship ($\beta = .126$, $p < .05$) were significant positive predictors of pursuing a career in industry, and being female ($\beta = -.117$, $p < .05$) was a significant negative predictor.

Model 3 and Model 4 predicting likelihood of a career in academia, Model 3 indicates that student characteristics explain 30.3% of the variance. Both master's students without thesis ($\beta = -.470$, $p < .001$) and master's students with thesis ($\beta = -.222$, $p < .001$) were negative predictors of pursuing career in academia, as compared with doctoral students. Being an international student ($\beta = .230$, $p < .001$) significantly predicted pursuing career in academia. In Model 4, independent variables, the identity scale, explained an additional 8.2% of variance in pursuing career in academia, while a total of 38.5% of variance was explained. Among the six identity variables, three variables significantly predicted likelihood of pursuing a career in academia. Research interest/recognition ($\beta = .328$, $p < .001$) and math/science competence ($\beta = .184$, $p < .01$) were significant positive predictors, while disciplinary engineering competence ($\beta = -.161$, $p < .01$) was a significant negative predictor. Significant students' characteristics variables in Model 3 remains significant in the Model 4.

Model 5 and Model 6 predict likelihood of a career in government, Model 5 indicates that graduate student characteristics explain 11.6% of the variance. Only master's without thesis ($\beta = -.324$, $p < .001$) was significant as a negative predictor of pursuing career in government (as compared with doctoral students). In Model 6, identity independent variables explained an additional 3.5% of variance in pursuing career in academia while a total of 15.1% of variance was explained by this model. Math/science competence ($\beta = .170$, $p < .05$) and research interest/recognition ($\beta = .159$, $p < .05$) were significant positive predictors of pursuing a career in government. In terms of characteristics, master's students without thesis ($\beta = -.214$, $p < .01$) and international students ($\beta = -.136$, $p < .05$) were less likely than domestic and doctoral students respectively to indicate pursuing career in government. I conducted F and Δ F tests, and these tests indicate that all Models are significant.

Table 4.3. *Results of Multiple Linear Regressions with Independent Variables*

Variables	Industry		Academia		Government	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Students' Characteristics						
Female	-.126*	-.117*	-.059	-.068	-.020	-.019
International	.072	.136*	.230***	.160**	-.043	-.136*
Civil/Environmental	-.087	-.084	.091	.056	.053	.076
Mechanical	.003	.018	-.021	-.050	.092	.067
Thesis Master's	.053	.023	-.222***	-.175**	.008	.036
Non-thesis Master's	.196**	.035	-.470**	-.308***	-.324***	-.214**
B.S. Degree in Engineering	.038	.013	-.053	-.015	-.068	-.025
Work Experience	-.068	-.051	.037	.030	.027	.015
Internship	.151*	.126*	-.101	-.086	-.076	-.061
Engineering Graduate Identity Scale						
Research Interest/Recognition		-.300***		.328***		.159*
Disciplinary Engineering Recognition		.186*		-.028		-.143
Math/Science Competence		.000		.184**		.170*
Disciplinary Engineering Interest		.093		-.099		.029
Disciplinary Engineering Competence		.091		-.161**		.001
Professional skills Competence		.086		.051		-.126
R^2	.062	.122	.303	.385	.116	.151
ΔR^2	-	.060	-	.082	-	.035
F test	2.58**	3.21***	11.90***	11.13***	4.54***	4.01***
Δ F test	-	4.06***	-	6.86***	-	2.70*

Note: $*p < .05$, $**p < .01$, and $***p < .001$.

4.4.3. Cluster Analysis for Likelihood of Career Paths

Since engineering graduate students may be considering multiple career paths simultaneously, I employed two-step cluster analysis to characterize their likelihood of pursuing industry, academia, and government careers. The cluster analysis revealed that the career paths of the engineering graduate students in this study can be categorized in three groups. I assigned descriptive names to these clusters: prefer industry, prefer academia, and open for all career options. Table 4.4 presents details of the clusters, including means and standard deviations for industry, academic and government, as well as number of doctoral, master's with thesis and master's without thesis students in each cluster.

Cluster 1 is labeled "prefer industry" to reflect the strong preference for an industry career path (mean = 4.28 on a 5-point scale) over academia (mean = 1.66) or government (mean = 2.62) path. This cluster has the majority of non-thesis master's students and the largest group of thesis master's students. Cluster 2 is similarly labeled "prefer academia," although the preference for academia (mean = 3.98) is much closer to that of government (mean = 3.59) and industry (mean = 3.11). These students are keeping several options open. This cluster is the smallest of the three, and as might be expected, includes very few master's without thesis students. Cluster 3 is labeled "open to all options" and indicates a slight preference for industry (mean = 4.24) over academia (mean = 3.68) or government (mean = 3.30). This cluster is the largest overall and includes over half of the doctoral students in the sample.

I also calculated representation of students by various characteristics (e.g., gender, nationality, degree program) in each cluster (Table 4.4). Compared to the entire sample, male students are overrepresented in the open to all options cluster, and female students are overrepresented in the prefer industry and prefer academia clusters. Domestic students are overrepresented in the prefer industry cluster while international students are overrepresented in the open to all options cluster. Doctoral students are overrepresented in the open to all options and prefer academia clusters, and master's students are overrepresented in the prefer industry cluster. Electrical/computer engineering students in this sample are overrepresented in the prefer industry and open to all options clusters. Civil and environmental engineering students are overrepresented in prefer academia, and mechanical engineering students are evenly distributed across clusters. One quarter of engineering graduate students in the prefer academia cluster had no internship experience during their engineering graduate programs while approximately 50% of students in the other clusters had internship experience.

Table 4.4. *Cluster Analysis Results*

		Cluster			
		Prefer Industry (n=103)	Prefer Academia (n=82)	Open to all options (n=135)	Total (n=320)
Industry Mean (S.D.)		4.28 (1.01)	3.11 (1.01)	4.24 (.52)	3.97 (.98)
Academia Mean (S.D.)		1.66 (.60)	3.98 (1.09)	3.68 (.61)	3.11 (1.26)
Government Mean (S.D.)		2.62 (1.21)	3.59 (1.09)	3.30 (.78)	3.15 (1.08)
Research Interest/Recognition Mean (S.D.)		3.45 (.95)	4.31 (.63)	4.08 (.69)	3.93 (.85)
Disciplinary Engineering Recognition Mean (S.D.)		4.12 (.63)	4.12 (.70)	4.08 (.66)	4.11 (.66)
Math/Science Competence Mean (S.D.)		3.61 (.59)	3.95 (.64)	3.89 (.64)	3.81 (.64)
Disciplinary Engineering Interest Mean (S.D.)		4.33 (.54)	4.28 (.69)	4.32 (.66)	4.32 (.63)
Disciplinary Engineering Competence Mean (S.D.)		3.59 (.82)	3.62 (.90)	3.68 (.83)	3.64 (.84)
Professional Skills Competence Mean (S.D.)		4.14 (.61)	4.03 (.65)	4.04 (.60)	4.06 (.62)
Gender	Female	28%	27%	19%	24%
	Male	72%	73%	81%	76%
Nationality*	International	37%	50%	57%	49%
	Domestic	54%	43%	30%	41%
Program	Doctoral	30%	66%	73%	57%
	Thesis Master's	27%	23%	14%	21%
	Non-thesis Master's	43%	11%	13%	22%
Major	Electrical/Computer	48%	28%	47%	42%
	Civil/Environmental	27%	45%	30%	33%
	Mechanical	25%	27%	24%	25%
Internship Experience**	Yes	49%	23%	45%	41%
	No	50%	73%	53%	57%
Entire sample of students		32%	26%	42%	100%

Notes: Means are based on items with Likert scale of 1 to 5 with 5 = strongly agree. S.D. abbreviates standard deviation.
* Out of 320 students, 33 students did not answer nationality question.
** Seven students did not answer internship experience question.

4.4.4. Multi-nominal Regression Models with Clustered Outcome Variables

I employed sequential multilevel logistic regression modelling to determine whether engineering graduate identity and student characteristics predict students' different types of career clusters. Because the clusters are related, and students are assigned to only one cluster, multilevel modeling allows for calculating the odds of a student appearing in one cluster over another. Each model compares two clusters; there are three combinations to compare all three clusters. Table 4.5 presents the results of the multinomial logistic regression that relates the three clusters as the dependent variable (i.e., prefer industry, prefer academia and open for all career options cluster) to students' characteristics variables and six identity independent variables. In Table 4.5, the reference group in Model 7 and 8 was prefer industry group comparison groups of prefer academia. The reference group in Model 9 and 10 was the prefer industry group comparison to open to all career options group. Model 11 and 12 presents prefer academia as the reference group compared to open to all career options group.

Coefficient values in the table represent odds ratios. An odds ratio of 1 indicates equal odds of a student being a part of the comparison group versus the reference group. Odds ratios less than 1 indicate a lower likelihood of a student being a part of comparison group than the reference group, and odds ratios larger than 1 indicate a greater likelihood of being a part of the comparison group than the reference group. One unit presents one unit on the 5-point Likert scale (1= strongly disagree and 5= strongly agree) in this survey.

Table 4.5 *Multinomial Logistic Regression Results (Odds Ratios)*

	Prefer academia vs. Prefer industry (ref)		Open to all options vs. Prefer industry (ref)		Open to all options vs. Prefer academia (ref)	
Variables	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Students' Characteristics						
Female	1.421	1.443	0.793	0.803	0.558	0.556
International	2.751**	1.176	3.298***	2.502*	1.199	1.420
Civil/Environmental	3.418**	3.821**	2.113	2.194	0.618	0.574
Mechanical	1.894	2.048	1.550	1.653	0.818	0.807
Thesis Master's	0.281**	0.386	0.225***	0.245**	0.800	0.636
Non-thesis Master's	0.100***	0.350	0.149***	0.291**	1.501	0.830
B.S. Degree in Engineering	0.463	0.659	0.478	0.669	1.031	1.016
Work Experience	1.888	2.002	1.181	1.257	0.626	0.628
Internship	0.395*	0.396*	1.011	0.998	2.559**	2.523*
Engineering Graduate Identity Scale						
Research Interest/Recognition		7.455***		2.535**		0.340**
Disciplinary Engineering Recognition		0.725		0.820		1.131
Math/Science Competence		2.486*		1.832		0.737
Disciplinary Engineering Interest		0.304**		0.566		1.861
Disciplinary Engineering Competence		0.673		0.762		1.132
Professional Skills Competence		.0.483		0.735		1.521
McFadden's$_{ADJ}$ R^2	0.036	0.053				
BIC	19.39	40.90				

Note: *p< .05, **p< .01, and ***p< .001. Ref: reference group. Com: comparison group

First two columns of Table 4.5 present the models comparing prefer industry to prefer academia. Model 7 includes student characteristics as predictors. The significant predictors in this model are international students, civil/ environmental students, master's thesis, master's non-thesis, and internship. International students were nearly three times (2.8) as likely to be in the prefer academia group relative to prefer industry group. Civil/environmental engineering students were more than three times as likely to be in the prefer academia group relative to the prefer industry group, as compared with electrical/computer engineering students. Non-thesis master's students were 10 (1/0.1) times and thesis master's students were 3.6 times (1/0.281) more likely to be in the prefer industry group than the prefer academia group. Graduate students who had internship experience during their current engineering graduate programs were 2.5 (1/0.395) times more likely to be in prefer industry group relative to prefer academia group.

Model 8 adds identity independent variables. Three identity independent variables are significant in model 2: research interest/recognition, math/science competence, and disciplinary engineering interest. Research interest/recognition was the strongest predictor of a student appearing in the prefer academia cluster as compared to the prefer industry cluster. For each one-unit increase research interest/competence, a student is 7.5 times more likely to prefer academia than to prefer an industry career path. Similarly, for each one unit increase in math/science competence, graduate students were 2.5 times more likely to be in the prefer academia cluster relative to the prefer industry cluster. Disciplinary engineering interest was a significant predictor in the opposite direction. For each one unit increase in disciplinary engineering interest, students were 3.3 times (1/0.304) more likely to be in the prefer industry cluster as compared to the prefer academia cluster. International, master's with thesis, and master's without thesis were significant in model 7 but not model 8, indicating that the variance can be explained by the added identity independent variables.

The Model 9 and Model 10 of Table 4.5 present the models comparing prefer industry to the open to all options. In Model 9, the significant predictors are international students, thesis master's, and non-thesis master's. International students were 3.3 times more likely to be in the open for all career options cluster relative to the prefer industry cluster. Non-thesis master's students were 6.7 times (1/0.149) and thesis master's students were 4.4 times (1/0.225) more likely to be in the prefer industry cluster than the open to all options cluster. In Model 10, which incorporates identity independent variables, research interest/recognition was a significant predictor. For each one unit increase in research interest/recognition, students were 2.5 times more likely to be in the open to all options cluster relative to the prefer industry cluster. All significant predictors in Model 9 were also significant in Model 10: international students, thesis master's and non-thesis master's.

The Model 11 and Model 12 present the models comparing prefer academia to open to all options. Model 11 shows one significant predictor: internship. Students who had internship experience during their engineering graduate programs were 2.6 times more likely to be in the open to all options cluster relative to the prefer academia cluster. In Model 12, research interest/recognition was a significant predictor. For each one unit increases in research interest/recognition, students were 4.2 times (1/0.340) more likely to be in the prefer academia cluster relative to the open to all options cluster. The significant predictor (internship) in Model 11 was also significant in Model 12.

Fit statistics suggest that the addition of engineering graduate identity factors improves the model. McFadden's adjusted R-squared is a pseudo-R-squared statistic used for evaluating goodness-of-fit of logistic models that penalizes models with a higher number of predictors. Relative to the baseline first model (Model 7, 9, and 11), McFadden's adjusted R-squared was higher in the second model (Model 8, 10, and 12), indicating a model with a greater likelihood even with the inclusion of additional variables.

4.5. Discussion

I utilized three analyses—multiple linear regression models, cluster analysis, and multinomial regression models—to understand master's and doctoral students' career paths toward industry, academia, and government. First, I ran separate multiple linear regression models for each employment sector, but these models explained less than 10% of the variance in students' likelihood of pursuing a career in industry, academia or government. To improve the explanatory value of our models and account for the possibility that students are considering multiple options simultaneously, I next conducted cluster analysis. Three clusters emerged: prefer industry, prefer academia, and open to all options. While the prefer industry group had a strong preference for industry over academia or government, the other clusters indicated students were keeping several options open. All 320 students in the sample were placed into a cluster, and no students were placed in multiple clusters. I ran a second set of regression models with student cluster membership as the dependent variable. Although the different types of regression analyses (multinomial regression and multiple linear regression) cannot be compared directly, the multinomial regression models of cluster membership provide additional explanation in terms of the ways graduate students are considering multiple career paths simultaneously and engineering graduate identity components that predict which career paths are most attractive to students. As expected, graduate students who had a higher research interest and research recognition from others were more likely to consider academic and government careers. Graduate students who had a higher disciplinary engineering interest were more likely to consider industry careers.

Among the most important results of this study is that cluster analysis indicates most engineering graduate students are keeping their options open. Students in the prefer industry cluster had the largest difference in likelihood of careers in industry, academia and government. However, the majority of respondents were assigned to the prefer academia or open to all options cluster. The prefer academia cluster indicated a slightly higher likelihood of academia over government or industry. This is appropriate given the increasing shortage of faculty positions in academia (Austin, 2010; Fiegener, 2010). Another interesting finding is that few PhD students ended up in the prefer industry cluster, so PhD students in particular are considering an array of employment options. Master's students, particularly non-thesis, are the ones for whom industry is the primary goal. Typically, there are very few employment opportunities in academia for those with terminal engineering master's degrees; in particular, non-thesis master's degrees are targeted preparation for industry. This study demonstrates empirically that most engineering doctoral students are seriously considering careers in industry and government, while most prior studies focus on doctoral students' paths toward faculty positions.

This study considered several aspects of engineering graduate identity: research interest/recognition, disciplinary engineering recognition, disciplinary engineering interest, disciplinary engineering competence, math/science competence, and professional skills competence. The factor analyses of the current data and a pilot survey provide insight into how engineering identity frameworks developed for undergraduates translate to the graduate level. As others have found (Choe & Borrego, in press; Perkins et al., 2018), I were able to adapt engineering disciplinary competence, interest and recognition scales to the graduate level. This was expected since most engineering graduate students hold bachelor's degrees in engineering. However, research competence, interest and recognition did not consistently emerge as separate factors, as another group has found in EFA of research-related items only (Perkins et al., 2018). In hindsight, this make sense since many graduate students are in the initial stages of their degree programs and do not have much knowledge of or confidence in research, which I attempted to capture with items such as "replicating key findings in journal papers" (Choe et al., 2017). Instead, our combined EFA identified a math/science competence factor and a professional skills factor. Several of these engineering graduate identity factors explain likelihood of careers in industry, academia, and government.

The research interest/recognition factor is the most important, since it was significant in all six models in which it was included and had the largest coefficient in linear regression models (Table 4.3) and the largest odd ratios in the logistic regression models (Table 4.5). This research interest/recognition factor explains both the level of students' interest in conducting research and the positive recognition a student gets as a researcher from others including advisors, peers, and colleagues. In the linear regression models (Table 4.3), research interest/recognition was a positive predictor of likelihood of a career in academia and government, and a negative predictor of a career in industry. In logistic regression models comparing clusters (Table 4.5), research interest/recognition increased the odds of being in the prefer academia cluster over the prefer industry cluster, open to all options over prefer industry, and prefer academia over open to all options.

This result is consistent with the findings of prior studies. Mosyjowski et al. (2017) found that students returning from full-time industry experience who have a goal of working in academia or government were more likely to express interest in conducting research as a part of their PhD training. Roach and Sauermann (2010) found that doctoral engineering and science students who preferred an industry career path had less interest in research aspects, and a greater concern for access to cutting-edge technology than students who preferred academia. Conti and Visentin (2015) reported that PhD engineers who were employed in academia in Switzerland published significantly more articles during their PhD training compared to those who were employed in industry.

Math/science competence was a significant predictor of pursuing a career in academia or government (Table 4.3) and also increased the likelihood of a student being in the prefer academia versus the prefer industry cluster (Table 4.5). There are few prior results with which to compare this finding directly. Again, Roach and Sauermann (2010) found that students interested in industry careers were more concerned about technology and students interested in academia more focused on research, which may require more fundamental application of math and science principles. At the undergraduate level, math and science competence have been associated with engineering career interest (Godwin et al., 2016), but it has also been shown that when engineering interest factors are included in models of engineering identity, math and science interest are not needed (Anita D. Patrick, Borrego, & Seepersad, 2018).

Disciplinary engineering interest and recognition were also significant predictors. Students with a one-unit increase in the 5-point disciplinary engineering interest scale were three times as likely to be in the prefer industry group relative to the prefer academia group (Table 4.5), and engineering interest was a negative predictor of likelihood of a career in academia (Table 4.3). Disciplinary engineering recognition was a positive predictor of likelihood of a career in industry (Table 4.3) but did not predict cluster assignments (Table 4.5). This finding that engineering interest is a stronger predictor than engineering recognition is consistent with studies of first- through fourth-year undergraduate students (e.g., A.D. Patrick et al., 2018). More broadly, the association of strong disciplinary engineering identity with pursuit of an industry career is consistent with Roach and Sauerman's (2010) finding that these students are particularly interested in access to cutting edge technology. However, this may be the first study to show that engineering disciplinary identity factors have a negative relationship with academic career paths. Students' identification with engineering is dependent on their perceptions of the engineering profession, which for graduate students would be based on their educational and work experiences. Most of the students in this sample hold undergraduate engineering degrees and have limited professional work experience. It is possible that they are basing their perceptions of engineering identity on undergraduate programs which emphasize bachelor's level industry work since that is the career path of the majority of engineering undergraduates. An important and interesting direction for future work would be to explore the perceptions and disciplinary engineering identities of students interested in graduate study and whether they believe master's and doctoral degrees can prepare them for industry careers.

This study did not find any significant relationships between students' professional skills competence and career paths, indicating that other factors are influencing students' desired career paths. It is notable that the professional skill competence level is uniformly high for all three clusters (Table 4.4). This suggests that students developed professional skills during graduate study and/or they perceived professional skills to be important for all potential career paths.

Internship experience was an important predictor for students to have greater likelihood of an industry career path versus academia. It is not clear from this data whether internships increase interest in an industry career or whether students already interested in industry pursue internship experiences. Nonetheless, it is notable that 48% students in the prefer industry cluster and 23% students in the prefer academia cluster have completed industry internships while graduate students. This is more promising support for how engineering graduate programs are preparing students for multiple career paths, as recommended by the recent National Academies report on STEM graduate education (National Academies of Sciences Engineering and Medicine, 2018).

Student background characteristics also predicted likelihood of a career in industry, academia or government (Table 4.3). In cluster analysis, more than 50% of US domestic students were assigned to the prefer industry cluster, while international students were much more likely to be in the open to all options or prefer academia clusters (Table 4.4). Due to their legal status in the US, international students would be less certain about employment opportunities in the US and are likely expanding their career paths to consider other countries. Employment opportunities may also vary considerably for international students, depending on their country of citizenship and whether their government is funding their graduate education. Female students were underrepresented in the prefer industry cluster (Table 4.4), although gender was only significant in the linear regression model for likelihood of working in industry (Table 4.3). This dataset also indicated a preference among civil and environmental engineering graduate students for academia and electrical and computer engineering students for industry (Table 4.5), but this may be characteristic of the institution and should be studied further before conclusions are drawn.

It was significant but not unexpected that master's students, particularly non-thesis master's students, reported particularly high likelihood of a career in industry (Tables 4.3 and 4.5). This is similar to the American Chemical Society's (2013) finding that doctoral students surveyed were more likely to be interested in becoming a professor compared to master's students. Chemistry master's students were more likely than doctoral students to want to work in government or educational administration/management, university research, or industry (American Chemical Society, 2013).

4.6. Implications

These findings reinforce the message that not all engineering graduate students aspire to faculty positions, and that graduate education should be reformed to prepare students for a broader range of potential careers (National Academies of Sciences Engineering and Medicine, 2018). Most engineering graduate students, particularly doctoral students and to a lesser extent thesis master's students, are keeping several options open. I don't know from this data whether students are being realistic about the job market (Reis, 1997; Roach & Sauermann, 2010; Thiry et al., 2007) or are genuinely undecided. Professional development programs for graduate students typically focus on future faculty, and some are emerging to focus on future industry professionals. I would argue for these programs to include advice on deciding among different options, or framing skills as useful in a wide range of careers, instead of forcing students to choose a "track" for their professional development activities. Internships are important but in some local settings may be discouraged for fear of disrupting students' degree progress. Again, it is not clear from this data whether graduate students self-select for an industry track before pursuing an internship or if the internship experience increases interest in an industry career. Nonetheless, removing any taboo associated with completing an industry internship as part of a thesis master's or doctoral engineering degree program would better prepare students for a wider and more realistic range of career options.

4.7. Limitations

I acknowledge several limitations. I conducted this study with students in three engineering disciplines at a single institution, and results are therefore not generalizable to the broader population of US engineering graduate students. Nonetheless, it is an important first step in studying industry, academia and government career paths of engineering graduate students. Although this study is relatively unique in its inclusion of master's students and distinguishing thesis and non-thesis master's students, there was not a good control for students earning a master's degree en route to a PhD. I asked students in which degree program where they were currently enrolled, with no option to indicate whether master's students intended (or had been admitted/approved) to complete a PhD before entering the workforce. Finally, "government" career opportunities and survey items may be interpreted very differently by students depending on their citizenship. Future work might consider additional detail in career paths toward industry, academia and government, for example in terms of management, research or teaching job functions.

4.6. Conclusion

This study provides additional insight into how and whether engineering doctoral and master's students are considering careers in industry, academia and government. Many students, and doctoral students in particular, are keeping multiple options open. A substantial portion of engineering graduate students are more interested in industry or government career paths than in the academic careers which are emphasized in most graduate student professional development programs. The results support recent calls for broader professional preparation for STEM graduate students. Aspects of engineering graduate identity, including research interest/recognition, math/science competence and engineering disciplinary interest and recognition were predictive of various career paths. Future work might explore when or how graduate students associate research, math and science with academia and government and engineering with industry, and whether this is appropriate for career preparation.

Chapter 5: Conclusion

This dissertation has addressed how engineering graduate students develop their identities as engineers and researchers. The components of these identities are Research Interest/Recognition, Disciplinary Engineering Competence, Disciplinary Engineering Interest, Disciplinary Engineering Recognition, Math/science Competence, and Professional (Interpersonal) Skills Competence. The survey instrument I developed explores the factors of engineering identity and research identity of engineering graduate students. It was developed in several steps as a part of this dissertation. These steps were (a) survey item generation (b) interviewing several key informants, (c) development of the initial instrument, (d) first survey data collection (e) initial item reduction, (f) second survey data collection (g) adding items and expanding engineering disciplines, (h) exploratory factor analysis for engineering identity factors, and (i) confirmatory factor analysis. These processes supported validity and reliability of the instrument.

This study demonstrates that frameworks previously developed for measuring the engineering identity of undergraduates can be adapted and applied to graduate students. Although frameworks of engineering identity (engineering interest, competence, and recognition) in this graduate study were labelled the same for undergraduates, engineering master’s and doctoral students perceived engineering interest, competence, and recognition differently than undergraduate engineering students based on the items for each factor. For example, while Interest items capture undergraduate students' interest in learning engineering and positive attitude toward engineering, graduate Interest items additionally captured interest in engineering work. One of the unique items from the graduate Engineering Interest scale is “I enjoy engineering activities as part of my work week.” Engineering Recognition items from the undergraduate survey did not reflect graduate students' engineering recognition initially. This study shows that recognition from the advisor and graduate student peers is important. Similarly, obtaining a bachelor's degree in engineering was an equally important recognition for engineering graduate students. While most undergraduate items measured students' engineering Competence and Performance based on classroom settings (e.g., doing well on exams), graduate items measured the competence level of more specific engineering skills such as designing, prototyping and finding solutions, which are important components of engineering design projects.

The framework for measuring research identity was also adapted from prior undergraduate engineering identity and graduate research identity studies. However, research identity framework still requires more revision to incorporate engineering graduate students' perceptions. In this dissertation, research interest/recognition was measured through twelve items represented by a single factor (see Appendix B).

This survey was administered at one large public research university within three disciplines. A total of 320 graduate students completed the survey resulting in a response rate of 26%. The exploratory factor analysis resulted in a six-factor solution shown in Table 5.1. These factors included Research Interest/Recognition, Disciplinary Engineering Competence, Disciplinary Engineering Interest, Disciplinary Engineering Recognition, Math/science Competence, and Professional (Interpersonal) Skills Competence.

Table 5.1. *Six Independent Variables and Description*

Variables	Description
Research Interest/ Recognition	Research interest describes the interest level of graduate students in research topics, as well as their interest in learning about and working on research. Research recognition from others represents engineering graduate students' perceptions of how others (e.g., advisor, peers, friends, family members) acknowledge their research identity.
Disciplinary Engineering Competence	Engineering graduate students' perceptions of their engineering abilities, knowledge, and skills relevant to engineering projects.
Disciplinary Engineering Interest	Engineering graduate students' interest in working on and learning about engineering.
Disciplinary Engineering Recognition	Engineering graduate students' perceptions of how others (e.g., advisor, peers, friends, family members) acknowledge their professional engineering work.
Math/science Competence	Engineering graduate students' perception on the level of their mathematics/science knowledge and skills in their graduate program.
Professional Skills Competence	Engineering graduate students' perception of their communication and collaboration knowledge, skills, and abilities.

In the second chapter (first manuscript), the academic factors included in several prior studies, engineering interest, competence, and recognition from others, explained 58% of the variance in how graduate students perceived their engineering identity. This is more than twice the variance explained in similar models of how undergraduate students perceive their engineering identity. Additionally, competence in interpersonal skills was the other important predictor of engineering identity for graduate students.

In the third chapter (second manuscript), I investigated differences between the engineering identity development of US and non-US graduate students by utilizing interaction factors in a linear regression model. In particular three constructs of graduate identity and nationality emerged as significantly predicting how students perceived their identity as engineers. Math/Science competence, engineering interest, and competence in interpersonal skills each influence the growth of engineering identity differently for US and non-US graduate students. Although US students' engineering identities are not influenced by math and science competence, non-US develop stronger identities as engineers when those skills are higher. In contrast, non-US graduate students' identities are not influenced by the level of their interpersonal skills, while US graduate students' identities significantly are influenced. Finally, the level of engineering interest positively influenced whether all students had a strong identity as an engineer, but the slope (strength of the relationship) was higher for US students. Understanding and considering these differences will help engineering graduate program staff to support both US and non-US students and foster their engineering identities.

In the fourth chapter (third manuscript), I utilized a cluster analysis to understand engineering graduate students' interest in industry, academia, and government careers, as it relates to their graduate engineering identities. Since engineering graduate students may be considering multiple career paths simultaneously, a cluster analysis characterizes their likelihood of pursuing industry, academia, and government careers. The career paths of the engineering graduate students in this study can be categorized in three groups. The three clusters were 'prefer industry', 'prefer academia', and 'open for all career options'. Table 4.4 presents details of the clusters, including means and standard deviations for industry, academic and government as well as engineering graduate identity components. The survey stems used to measure career intention were "How likely are you to pursue each of the following career options after graduation?" The industry item was worded as "profit sector (industry) engineer." The academia item was worded as "college professor/postdoctoral researcher." Lastly, the government item was worded as “government engineer, e.g., at a national lab.” The students responded on 5-point Likert-scales where 1 corresponds to “definitely no” and 5 to “definitely yes.” The engineering graduate identity components were also asked in 5-point Likert-scales. The survey stems read “To what extend do you agree or disagree with the following statements?” for recognition or interest items, and the stems read “How competent are you with the following tasks?” for measuring competence.

As expected, regression models indicate graduate students who had a higher research interest and research recognition from others were more likely to consider academic and government careers. Graduate students who had a higher disciplinary engineering interest were more likely to consider industry careers. In addition, cluster analysis indicates engineering graduate students, particularly doctoral students, are keeping their career options open. Students who preferred industry had the largest difference in likelihood of careers in industry, academia and government. However, most respondents preferred academia or were open to all options. The prefer academia cluster indicated just a slightly higher likelihood of academia over government or industry.

Table 4.4. *Cluster Analysis Results*

		Cluster			
		Prefer Industry (n=103)	Prefer Academia (n=82)	Open to all options (n=135)	Total (n=320)
Industry Mean (S.D.)		4.28 (1.01)	3.11 (1.01)	4.24 (.52)	3.97 (.98)
Academia Mean (S.D.)		1.66 (.60)	3.98 (1.09)	3.68 (.61)	3.11 (1.26)
Government Mean (S.D.)		2.62 (1.21)	3.59 (1.09)	3.30 (.78)	3.15 (1.08)
Research Interest/Recognition Mean (S.D.)		3.45 (.95)	4.31 (.63)	4.08 (.69)	3.93 (.85)
Disciplinary Engineering Recognition Mean (S.D.)		4.12 (.63)	4.12 (.70)	4.08 (.66)	4.11 (.66)
Math/Science Competence Mean (S.D.)		3.61 (.59)	3.95 (.64)	3.89 (.64)	3.81 (.64)
Disciplinary Engineering Interest Mean (S.D.)		4.33 (.54)	4.28 (.69)	4.32 (.66)	4.32 (.63)
Disciplinary Engineering Competence Mean (S.D.)		3.59 (.82)	3.62 (.90)	3.68 (.83)	3.64 (.84)
Professional Skills Competence Mean (S.D.)		4.14 (.61)	4.03 (.65)	4.04 (.60)	4.06 (.62)
Gender	Female	28%	27%	19%	24%
	Male	72%	73%	81%	76%
Nationality*	International	37%	50%	57%	49%
	Domestic	54%	43%	30%	41%
Program	Doctoral	30%	66%	73%	57%
	Thesis Master's	27%	23%	14%	21%
	Non-thesis Master's	43%	11%	13%	22%
Major	Electrical/Computer	48%	28%	47%	42%
	Civil/Environmental	27%	45%	30%	33%
	Mechanical	25%	27%	24%	25%
Internship Experience**	Yes	49%	23%	45%	41%
	No	50%	73%	53%	57%
Entire sample of students		32%	26%	42%	100%

Notes: Means are based on items with Likert scale of 1 to 5 with 5 = strongly agree. S.D. abbreviates standard deviation.
* Out of 320 students, 33 students did not answer nationality question.
** Seven students did not answer internship experience question.

Future Work

Future work for this dissertation data set may include an exploratory factor analysis with only research identity construct items. In the second chapter (first manuscript), I validated the scale for engineering identity factors (engineering performance/competence, engineering interest, and engineering recognition), and the results from the survey instrument contributed to understanding how engineering graduate students develop their identity as engineers. Similarly, it is also necessary to explore and validate the research identity constructs for engineering graduate students since validating research identity factors will explain how these research identity factors are related to students' research identity, retention, and career intentions. Second, future study may include the intersectionality of nationality and gender to compare students' engineering and research identities among international female, international male, domestic female, and domestic male students.

The results from this study also suggest several avenues for continued research outside of this project data set in both quantitative and qualitative approaches. In terms of qualitative approaches, some results from this dissertation can be explored using rich descriptions gather from interviewing and observing. For instance, gender was not a significant predictor of engineering identity for graduate students, unlike undergraduate students. Although several researchers investigated female engineering graduate students, it is worth researching how or why females' engineering identities in graduate programs are as strong as those of males. In addition, future work can explore why engineering graduate students' engineering experiences such as industry work experience prior to graduate programs and internship experience in graduate programs were not significant predictors of engineering identity because it contrasts to undergraduates' studies. For example, D'Angelo, Arastoopour, Chesler, and Shaffer (2011) reported that internship experience in undergraduate program positively influenced students' identification as engineers. Additionally, an ethnographic study to observe graduate students' daily events in the lab and research meetings may help better understand relationships and overlaps between research identity and engineering identity.

In terms of quantitative approaches, additional survey data collections are needed to validate the engineering identity instrument from this study. This survey was only administered at one large public research university within three disciplines: electrical/computer, civil/environmental, and mechanical engineering. Collecting survey information from other institutions, both public and private, and in different disciplines such as aerospace, biomedical, and chemical engineering will help determine whether the engineering identity instrument can be utilized generally for US engineering graduate students. More importantly, validation of the engineering identity instrument will be determined by collecting more survey data.

In addition, interpersonal skills competence factor can be expanded to encompass other professional skills competence such as decision making, leadership, working as a team, and negotiation. In this dissertation, I limited the professional skills within interpersonal skills such as verbal, oral, and written communication skills. However, graduate programs facilitate students to equip not only interpersonal skills but also various professional skills. Therefore, future researchers can develop survey items that measure other professional skills for engineering graduate students and test whether these professional skills foster students' engineering identities.

Longitudinal survey study will allow for measuring changes in identity over time, especially for doctoral students, as well as linking identity data to actual completion rates. In this dissertation, year of program was not a significant predictor of engineering identity in the cross-sectional survey; however, it will be interesting to see how individuals change their identities over time.

Finally, the use of cluster analysis in conjunction with regression models (in Chapter 4) identified some groups of students with similar and different career aspirations. Considering that individuals have different levels of intention in pursuing each career path, grouping students who have similar career paths helps institutions and advisors to provide different career supporting strategies within the groups. This cluster analysis technique is relatively new in engineering education research and may be utilized effectively in other studies of career interest or other situation where students are considering multiple future possibilities simultaneously.

Appendix A

Graduate Identity Survey

You have been asked to participate in a research study about people's views and experiences with your graduate school program.

[Informed Consent Question]

Section 1: Demographics

1. What discipline did you receive your bachelor's degree in?

- o Engineering
- o Natural science and Mathematics
- o Other ____

2-1. How many months did you participate in internship(s) or co-op(s) in industry, government or non-profit sectors during your graduate program?

(Drag the bottom bar to show the exact month)

	Month(s)						
	0	12	24	36	48	60	72
In engineering field ()							
In science field ()							

2-2. How many years, if any, have you worked **full time** in industry, government or non-profit sectors **between undergraduate and graduate school**?

(Drag the bottom bar to show the exact **year**)

	Year(s) 0 3 6 9 12 15 18 21 24 27 30
In engineering field ()	
In science field ()	

3. What degree program are you currently enrolled in?

- Master's degree – thesis option
- Master's degree – non-thesis option
- Ph.D. degree

4. Do you intend to complete your current program? (Mark one)

- Definitely Not
- Probably Not
- Not sure
- Probably Yes
- Definitely Yes

5. How likely are you to pursue each of the following career options after graduation?

(Mark Response for each career option)

	Definitely Not (1)	Probably Not (2)	Not Sure (3)	Probably Yes (4)	Definitely Yes (5)
(a) Profit sector (industry) engineer					
(b) College professor / Postdoctoral researcher					

(c) Government engineer, e.g., at a national lab

(d) Self-employed engineer

(e) Non-Profit sector engineer

(f) Other engineering

(g) Something else outside of engineering

Display Q6 Question: If 3. What degree program are you currently enrolled in? = Ph.D. degree

6. Which discipline did you receive your master's degree in?

- Engineering
- Natural science or math
- No, I have not received a master's degree
- Other ____

6-1. Which year of your current program are you in?

- 1st year
- 2nd year
- 3rd year
- 4th year
- 5th year
- 6th year
- More than 6th year

6-2. How is your research primarily conducted? (Mark one)

- o Experimental
- o Theoretical
- o Both (experimental and theoretical)
- o Not applicable
- o Other ____

Display Q6-3 Question: If 3. What degree program are you currently enrolled in? = Ph.D. degree

6-3. How many years, if any, have you worked **full time** in industry, government or non-profit sectors **between your master's and Ph.D. program**?

(Drag the bottom bar to show the exact year)

	Year(s) 0 3 6 9 12 15 18 21 24 27 30
In engineering field ()	
In science field ()	

Display Q6-4 Question: If 3. What degree program are you currently enrolled in? = Ph.D. degree

6-4. Have you advanced to candidacy?

- o Yes

- No

7. How many accepted or published journal articles have you been an author or coauthor on?

- None
- 1
- 2
- 3
- 4
- 5
- More than 5

8. How many conference papers, posters or presentations have you been an author or coauthor on?

- None
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9

- More than 9

9. How many patents do you have?

- 1
- 2
- 3
- 4
- 5
- More than 5

Section 2: Identity Questions

Instruction: For the following questions, please fill in your answers as indicated.

10. How competent are you with the following tasks? (MARK ONE RESPONSE ON EACH LINE)

Not Competent (1)	(2)	(3)	(4)	Highly Competent (5)

(a) Communicating verbally, for example in discussion with others

(b) Presenting my professional work to others

(c) Building and testing systems to learn more about how they work

(d) Identifying technical solutions that are as simple as possible

(e) Designing and conducting experiments to test an idea or learn more about a system

(f) Applying math and science concepts to make new systems/models

(g) Communicating visually, for example using drawings or prototypes

(h) Designing and conducting experiments to test a research idea

(i) Creating prototypes to test an idea

(j) Designing a system, a part/component of a system, or a process based on realistic constraints

(k) Understanding and applying scientific and mathematical relationships based on the conditions

(l) Convincing others to accept my ideas

(m) Working collaboratively in teams

(n) Using equipment safely and efficiently

(o) Utilizing software program to make a prototype

(p) Communicating my ideas in writing

11. How competent are you with the following tasks? (MARK ONE RESPONSE ON EACH LINE)

Not Competent (1)	(2)	(3)	(4)	Highly Competent (5)

(a) Obtaining research articles relevant to my research from library systems or online

(b) Understanding derivations and equations in journal papers

(c) Searching for innovative ways to do things

(d) Understanding current research findings by using sufficient math, science or engineering knowledge

(e) Keeping up to date on research topic(s)

(f) Simulating mathematical or scientific phenomena in my research by using software programs

(g) Generating research hypotheses for research

(h) Improving a design to make it more efficient (faster, better, cheaper)

(i) Understanding research trends and topic(s)

(j) Understanding the engineering concepts underlying projects

(k) Learning new things from people I'm working with

(l) Replicating key findings in journal papers

(m) Following the logic of authors' arguments

(n) Working with people with different skills and interests

(o) Using calculations and equations to evaluate things

12. To what extent do you disagree or agree with the following statements? (MARK ONE RESPONSE ON EACH LINE)

Strongly disagree (1)	(2)	(3)	(4)	Strongly agree (5)

(a) I consider myself an engineer

(b) I feel strong ties to other engineers in my discipline

(c) Society views engineers as an asset

(d) Being a researcher is an important reflection of who I am

(e) I am proud to be an engineer

(f) I feel strong ties to other researchers in my discipline

(h) Society views researchers as an asset

(g) I am proud to be a researcher

(i) Being an engineer is an important reflection of who I am

(j) I consider myself a researcher

13. To what extent do you disagree or agree with the following statements? (MARK ONE RESPONSE ON EACH LINE)

Strongly disagree (1)	(2)	(3)	(4)	Strongly agree (5)

(a) I like doing engineering

(b) My advisor sees me as an engineer

(c) In general, I find working on engineering projects interesting

(d) I am interested in my research topic

(e) My advisor gives positive feedback on my research work

(f) I am interested in my engineering work

(g) My peers view me as an engineer

(h) I am interested in learning more about research

(i) I dislike doing engineering

(j) I enjoy research activities as part of my work week

(k) My advisor gives positive feedback on the engineering aspects of my work

(l) I am interested in learning more about engineering

(m) I enjoy engineering activities as part of my work week

(n) Other attendees at professional conferences show interest in the engineering aspects of my presentations

(o) In general, I find working on research interesting

(p) I like doing research

(q) My peers view me as a researcher

(r) My advisor sees me as a researcher

(s) Other attendees at professional conferences show interest in my research presentations

(t) In general, I find working on research uninteresting

14. To what extent do you disagree or agree with the following statements? (MARK ONE RESPONSE ON EACH LINE)

Strongly disagree (1)	(2)	(3)	(4)	Strongly agree (5)

(a) My advisor thinks that I do good work

(b) My friends see me as an engineer

(c) Having an engineering degree makes me feel like an engineer

(d) I enjoy doing my current research

(e) My family sees me as an engineer

(f) My current research topic aligns with my research interest

(g) Other students in my program see me as a researcher

(h) My family sees me as a researcher

(i) Getting my paper accepted validates me as a researcher

(j) My advisor expects me to continue my career as an engineer

(k) Other students in my program see me as an engineer

(l) My friends see me as a researcher

15. I are interested in knowing why you are or were studying engineering. Please indicate below the extent to which the following reasons apply to you (MARK ONE RESPONSE ON EACH LINE)

Strongly disagree (1)	(2)	(3)	(4)	Strongly agree (5)

(a) Technology plays an important role in solving society's problems

(b) I feel good when I am doing engineering

(c) I like to build stuff

(d) Engineers have contributed greatly to fixing problems in the world

(e) I think engineering is fun

(f) I like to figure out how things work

(g) Engineering skills can be used for the good of society

(h) I think engineering is interesting

Section 3: Additional Demographics

16. What is your gender?

- Male
- Female
- Prefer not to Answer
- Other ____

17. Are you US citizen or permanent resident?

- Yes
- No

Display 17-1 Question: If 17. Are you US citizen or permanent resident? = Yes

17-1. What is your race/ethnicity?

- o African-American/Black
- o Asian-American/Pacific Islander
- o European-American/White
- o Latino/Chicano/Hispanic
- o Middle Eastern/Arab-American
- o Native American/American Indian
- o Multi-Ethnic
- o Other ____
- o I do not want to answer

Display 17-2 Question: If 17. Are you US citizen or permanent resident? = No

17-2. What is your nationality?

____

Display 17-3 Question: If 17. Are you US citizen or permanent resident? = No
17-3. What is your present level of English fluency?

- o Very poor
- o Poor
- o Neutral
- o Good
- o Very good

Display 17-4 Question: If 17. Are you US citizen or permanent resident? = No

17-4. How comfortable are you communicating in English?

- Very uncomfortable
- Uncomfortable
- Neutral
- Comfortable
- Very comfortable

Display 17-5 Question: If 17. Are you US citizen or permanent resident? = No

17-5. How often do you communicate in English?

- Never
- Rarely
- Sometimes
- Often
- Always

18. Do any of your immediate family members (parents, siblings) hold an engineering degree?

(MARK ONE RESPONSE ON EACH LINE)

	Yes	No
(a) Mother	○	○
(b) Father	○	○
(c) Other family member (excluding parents)	○	○

19. What is the highest level of education that your mother completed? (Mark one)

- o Graduated from high school or equivalent GED or less
- o Degree or certificate from a vocational school, a junior college, a community college, or another type of 2-yr. school
- o Completed a College degree
- o Completed a Masters, Doctoral or other advanced professional degree (JD, MD, PhD, etc.)

Thank you for participating this survey.

To access the amazon.com gift card webpage, please click on the link blow.

If the link does not open automatically, please copy and paste the following link your internet browser's address bar.

[The link]

Please, provide your email address to apply the drawing for the $50 amazon.com gift card.   Your email address will be only used for the drawing.   I will contact you if you are selected to the drawing.

Appendix B

Exploratory Factor Analysis Results for Survey Measures of Engineering Graduate Identity Scale

Factor	Survey Items	Factor Loading
Research Interest/ Recognition	My peers view me as a researcher	0.94
	My advisor sees me as a researcher	0.89
	Other students in my program see me as a researcher	0.89
	I like doing research	0.87
	In general, I find working on research interesting	0.84
	My friends see me as a researcher	0.84
	My family sees me as a researcher	0.81
	I enjoy research activities as part of my work week	0.77
	I enjoy doing my current research	0.73
	I am interested in learning more about research	0.72
	Other attendees at professional conferences show interest in my research presentations	0.68
	My current research topic aligns with my research interest	0.66
	I am interested in my research topic	0.62
	My advisor gives positive feedback on my research work	0.56
Disciplinary Engineering Competence	Building and testing systems to learn more about how they work	0.82
	Designing and conducting experiments to test an idea or learn more about a system	0.67
	Creating prototypes to test an idea	0.66
Disciplinary Engineering Interest	I think engineering is interesting	0.81
	I think engineering is fun	0.75
	I like to figure out how things work	0.70
	I feel good when I am doing engineering	0.63
	I am interested in learning more about engineering	0.53
Disciplinary Engineering Recognition	Other students in my program see me as an engineer	0.91
	My friends see me as an engineer	0.68
	My peers view me as an engineer	0.68
	My family sees me as an engineer	0.67
	My advisor sees me as an engineer	0.59
	My advisor expects me to continue my career as an engineer	0.58
	Having an engineering degree makes me feel like an engineer	0.50
Math/Science Competence	Understanding and applying scientific and mathematical relationships based on the conditions	0.71
	Understanding derivations and equations in journal papers	0.70
	Using calculations and equations to evaluate things	0.69
	Understanding current research findings by using sufficient math, science or engineering knowledge	0.68
	Applying math and science concepts to make new systems/models	0.64
	Simulating mathematical or scientific phenomena in my research by using software programs	0.53
	Understanding research trends and topic(s)	0.48
	Following the logic of authors' arguments	0.48
Professional Skills Competence	Communicating verbally, for example in discussion with others	0.83
	Presenting my professional work to others	0.79
	Communicating my ideas in writing	0.59
	Working collaboratively in teams	0.49
	Working with people with different skills and interests	0.48

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